# ELECTRICAL RATES

G. P. WATKINS

Robert J. Corcoran

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BY

G. P. WATKINS, PH. D.

Formerly Assistant Chief Statistician of the
New York Public Service Commission
for the First District

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*DEDICATED*
*TO*
*MY MOTHER*

## PREFACE

This book is an outgrowth, and in fact a by-product, of the author's practical work. But it is his purpose to offer more of explanation and of constructive application of economic principles than most work of such a nature does, and to go farther into fundamental economic questions than most practical men, especially business men, are likely to go.

The standpoint of the writer is that of the economist. This fact largely explains the amount of attention given to differential rate theory. Few engineers appear to appreciate the character and importance of the principle of differentiation in rate-making, though they accord it piecemeal recognition under various other names, especially in discussions of "value of service." Economists, while they have given much attention to railroad rates, have interested themselves comparatively little in the related subject of electrical rates. Hence, we should not be surprised to find that the subject has hitherto been handled with too little reference to the composite character and variable nature—variable, that is, aside from changes in costs and prices with time—of the unit cost of electricity.

The subject of load factors naturally occupies a large place in the book, as it does in the discussion of electrical rates generally. In this connection the writer's emphasis upon diversity and his conception of its relation to the occasion and amount of demand charges constitute what is characteristic and most important in his viewpoint. Engineers too often ignore diversity as an element in rate theory.

But the writer's conception of the importance of the density factor—which relates to the other most discussed phase of electrical rate-making—and of how it should influence the rate schedule is more distinctly or more largely his own.

The question as to what the average level of electrical rates should be is not here discussed. Not only is this, from the point of view of economics, a comparatively simple question, but under stable business conditions it is, in practice, a question to be decided

with reference to local conditions and for a particular supply company. It is true that the instability of business conditions during and since the War gives to the matter of price levels a very great present importance; but this situation only fortifies the reasons for not professing to dispose incidentally of a problem calling for independent consideration. The subject of relations between different rates granted by the same company to different classes of consumers, by itself, requires sufficiently extended examination from a general or scientific standpoint.

The author lays no claim to being absolutely correct and up to date in all the technological details that are directly or indirectly involved in the consideration of his subject. If our engineers were as well versed in economics as in engineering, a mere economist would have no excuse for undertaking to deal with the subject of this book.

Grateful acknowledgments are due to Professor F. W. Taussig for effective encouragement to complete and publish this book, which he has seen in manuscript at an earlier stage of its development; and to Professor Comfort A. Adams, who also has read the manuscript and whose favorable judgment of it was particularly encouraging because suggesting that, according to the impressions of an eminent electrical engineer, the technological implications of the study are substantially correct. However, not merely on general grounds, but also because the manuscript has been considerably revised and extended since it was seen by these gentlemen, neither of them is in any degree responsible for the opinions expressed.

The book is an outgrowth of nine years experience and interests developed in the statistical bureau of a public service commission. My incidental indebtedness to associates in that work is doubtless large, but is not susceptible of specification except as regards obligations to Mr. L. H. Lubarsky for the construction—by which I do not mean the mere draughting—of the diagrams, with the exception of Diagram III. I have also in a few instances sought and received valuable information from commissions and public utility companies.

Chapter VII is mainly a reprint, with some additions and minor changes, of an article published in *The Quarterly Journal of Economics* for August, 1916. Several of the diagrams have also been previously published. Diagram II and Figures 2 and 4 were used

by the writer in an article in *The Quarterly Journal of Economics* for May, 1916, entitled "Electrical Rates: The Load Factor and the Density Factor." Diagram I and Figure 5 have appeared in annual reports of the New York Public Service Commission for the First District, the former in volume III for 1913, the latter in volume III for 1915.

G. P. WATKINS.

WASHINGTON, D. C.,
April 17, 1921.

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# CHAPTER I

## THE PECULIAR INTEREST AND IMPORTANCE OF ELECTRICAL RATES

Importance and interest of the subject. Nature of the genus of which electrical rates are a species. Heavy fixed charges generic and the importance of the load factor specific.

*The load factor.* This and related terms as defined by the American Institute of Electrical Engineers. Description and significance of the load factor. Unutilized capacity. Illustration by load curves. Factors of certain large systems. The load factor an economic matter. Limited applicability to gas rates.

*Further matters of economic technology.* "Increasing returns." The capacity of generating units. Range of capacity of central stations. Tendency to centralization. The density factor. Continuous rating and overload capacity. Qualifications of the significance of ratings. Alternating and direct current systems. Interconnection of power plants.

*The development and importance of electricity supply.* The growth of less than four decades. The hydro-electric element. Comparisons with other industries. The lowering of average rates.

*The problem confronting regulating bodies.* Legal precedent and the administrative situation not subjects of study in this essay. Lack of established administrative policies as regards electrical rates. Adequacy of powers. Diffidence of commissions.

To obtain the means of satisfying any and every want by "pressing the button" has become proverbial as suggesting the easy accomplishment of large results. The reference is to actual achievements and idealized possibilities of the use of electricity. Upon analyzing the notion with a view to determining just what is implied, one finds an underlying assumption of elaborate material equipment and adjustments in preparation for "pressing the button." The ease achieved presupposes heavy investment in fixed capital as well as invention and engineering contrivance. This situation is characteristic of the use of electricity. Payment for such use must reflect these conditions. The utilization of energy from a waterfall a hundred miles away in preparing one's breakfast—perhaps eaten early and by electric light—on the table by turning on the current for an electric percolator, toaster, etc., presents a problem in the adjustment of the payment for the services involved that is incomparably more complex than is, for example, the payment of a servant to prepare the breakfast in the kitchen and place it on the table.

Electrical rates and railroad rates are species of the same genus. The latter have constituted one of the most discussed economic and administrative problems of our time. Electrical rates having the general character indicated, if they have also outstanding peculiarities of their own, should be of great economic interest.

Heavy investment of fixed capital, both absolutely and in proportion to total capital, is, according to many economists, the principal explanatory key to the general problem of differential rates. Others emphasize the possession of monopoly power by the enterprises in question. But in either case the economic similiarity between an electric central station and a railroad is evident. The business of electric supply ranks very high in respect of proportion of fixed capital employed and is likewise a monopolistic public service, hence it presents the underlying conditions productive of complex and differential rates. When account is taken of the rapid obsolescence of electrical apparatus, for which due allowance must be made among carrying charges, it is possible that the proportion of revenues that must be devoted to fixed charges in this broader sense is higher for this particular class of public-service enterprises than for any other. But for present purposes it suffices merely to mention this point.

The great distinguishing characteristic of electrical rates, however, is due to the load factor. But the significance of the load factor is in turn dependent upon heavy investment of fixed capital.

## The Load Factor

The load factor is the ratio of average to maximum demand. For a more formal and authoritative definition the reader is referred to the Standardization Rules of the American Institute of Electrical Engineers, which cover also several other terms more or less distinctive of electricity supply of which use is made in this book.[1] The load factor is of general economic interest as well as of peculiar importance for electrical rates.

[1] Following are various definitions as quoted from the Standardization Rules, edition of 1916. Occasional comment of the writer is put in brackets.

*The Load Factor* of a machine, plant or system. The ratio of the average power to the maximum power during a certain period of time. The average power is taken over a certain period of time such as a day, a month, or a year, and the maximum is taken as the average over a short interval of the maximum load within that period.

In each case, the interval of maximum load and the period over which the average is taken should be definitely specified, such as a "half-hour monthly" load factor.

By load is meant the kilowatts carried by a power station or generator or other machine, or the kilowatts required by a consumer or group of consumers. Kilowatts, though primarily a measure of capacity, in this connection serve to measure the rate of output or of consumption of energy. The rate of output at a given time corresponds to the utilized capacity, or the load, at that time. A rate of output of one kilowatt kept up during one hour gives a quantity of output of one kilowatt hour. So, in order to arrive at the *average* output (or average load) of some specified power

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The proper interval and period are usually dependent upon local conditions and upon the purpose for which the load factor is to be used.

*Plant Factor.* The ratio of the average load to the rated capacity of the power plant, that is, to the aggregate ratings of the generators. [This conception is familiar in the gas industry under the name *capacity factor* and the idea is of general economic applicability and significance. Doubtless the Standards Committee wishes to make the term specific, "capacity" having too general a reference.]

*The Demand of an Installation or System* is the load which is drawn from the source of supply at the receiving terminals averaged over a suitable and specified interval of time. Demand is expressed in kilowatts, kilovolt-amperes, amperes, or other suitable units. [It is inevitable that "demand" will be used also in the economic sense, meaning the quantity that will be taken at a specified price. The phrase "average demand" relates both to this and to the above conception.]

*The Maximum Demand of an Installation or System* is the greatest of all the demands that have occurred during a given period. It is determined by measurement, according to specifications, over a prescribed time interval. [The change made in this definition in 1916 leaves it in principle the same, but the previous wording—which was "greatest demand, as measured not instantaneously, but over a suitable and specific interval, such as 'a five-minute maximum demand'"—is interesting for its negative emphasis.]

*Demand Factor.* The ratio of the maximum demand of any system, or part of a system, to the total connected load of the system, or of the part of the system, under consideration.

*Diversity Factor.* The ratio of the sum of the maximum power demands of the subdivisions of any system or parts of a system to the maximum demand of the whole system or of the part of the system under consideration, measured at the point of supply. [An individual consumer, of course, has no diversity factor. But he may be said to have a *diversity* in relation to the combined peak, which may be considered proportionate to the difference between his demand at the time of the combined peak in question and his individual peak, or else to the ratio between his rate of consumption then and his average rate of consumption. The second is the more significant point and is important enough to have a name of its own. *Diversity ratio* seems to be appropriate.]

*Connected Load.* The combined continuous rating of all the receiving apparatus on consumers' premises, connected to the system or part of the system under consideration.

*Power Factor.* The ratio of the power [cyclic average of the products of current and voltage in an alternating current circuit, as indicated by a wattmeter] to the volt-amperes. [Chiefly of technological interest.]

The terms load factor and diversity factor were both current in various senses before (and to a considerable extent since) their official recognition and definition by the American Institute of Electrical Engineers, the former in June, 1907, the latter in June, 1911, by action of its Board of Directors.

As supplementary to the definition of load factor adopted by the American Institute of Electrical Engineers, the following rules of the Association of Edison Illuminating Com-

station for a year it is only necessary to divide the kilowatt-hour output for the year by 8760, the number of hours in the year; which gives one term of the load-factor ratio.

The other term is the *highest* recorded output for some brief interval—five minutes, fifteen minutes, or half an hour, or possibly longer. Sometimes the instantaneous maximum has been used, but the American Institute of Electrical Engineers disapproves this, doubtless because the capacity of a generator for a brief interval is much greater than its continuous rating, so that the technical and economic significance of a load factor based upon an instantaneous maximum, probably the result of a brief fluctuation of the load, is less than where the load for some appreciable interval is taken. It should perhaps be noted that the latter sort of maximum load is strictly the average kilowatts for the interval in question, though of course measured integrally, instead of being derived by an arithmetical operation upon a series of measurements, that is, by "averaging."

The load-factor concept has been developed in connection with the electric-supply industry because of the fact that electricity must be generated at the moment of consumption and cannot be "manufactured for stock," even a few hours ahead. In manufactures, goods are made in anticipation of need, and are stored until consumers are ready to buy and an economic demand for the goods results. In the gas industry storage is possible, though the capacity of gas holders is seldom more than one day's supply. In electricity supply storage is not yet economically practicable. The energy must be generated at the moment of demand. Accord-

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panies, adopted on recommendation of its Committee on Load Factor in 1914, are of interest. Proceedings are not published.

(a) Unless definitely stated to be otherwise, the period for which the load factor is calculated should be taken as one year.

(b) In calculating the load factor of central station systems the consumption of energy should be taken as of the calendar year; the maximum demand should be taken as the average of the maximum load of the winter in which the year begins and of the winter in which the year ends. Should the maximum load occur near the middle of the calendar year, that load should be taken as the maximum demand of the year.

(c) For central station calculations the maximum load should be taken as the highest half-hour average load during the year. It is suggested also that the half-hour time intervals be taken always to extend over the clock half hours.

(d) For industrial power service calculations the maximum demand should, unless definitely stated to be otherwise, be taken as the highest half-hour average load during the period. Different time intervals varying from one hour to the instantaneous demand may, however, be specified for industrial power and for railroad service, depending upon the local conditions and the characteristics of the special service.

ingly grates and boilers must be designed so that the quantity of water vaporized can be doubled on a moment's notice, and the generators must be able to take care of rapid changes in the load. Irregularity of economic demand and its concentration upon peak hours are therefore very costly and require special attention in rate-making. A qualification is necessary, however, with reference to the overload capacity of generating and other equipment, available for brief intervals of time. Some degree of operating elasticity is obtainable in this way. But the carrying of an overload for any considerable period of time causes a destructive overheating of the machine.

The operating problems occasioned by the peak load are, however, of comparatively small general bearing. If engineers and managers were not able to meet them they could not retain the business. At the steam end, devices have been perfected to permit of greatly increasing almost instantaneously the amount of water vaporized, and the adaptability of generators to variations in the load has also been greatly increased. So far as sharp and sudden peaks increase operating costs, the costs should of course be recovered, if possible in the rates charged to consumers responsible for them.

The more fundamental aspect of the importance of the load factor to the electrical company is the necessity of providing a plant sufficient to meet maximum demand. Most of the time the capacity of the plant is utilized only to a small extent. A consumer who takes energy almost exclusively at the "peak of the load" requires generating capacity proportionate to the rate of supply necessitated at that time, for which capacity there may be no use at other times. A consumer whose demand is entirely "off-peak," on the other hand, requires no additional plant capacity and imposes no fixed charges attributable directly to him. It is obvious that the same kilowatt-hour rate for both is not *prima facie* equitable.

Load curves are the best means of indicating the character of the variation of the load for different companies and different periods. The diurnal variation most readily lends itself to graphic representation, though there is a characteristic seasonal variation or cycle that is of scarcely less importance, and there is also a weekly cycle. Following are diagrams illustrative of the character of

diurnal load curves. The first compares winter and summer diurnal curves for several New York City companies; the second shows the development of the curve of the Commonwealth Edison Co. of Chicago through a series of years; the third shows the development from 1907 to date of the load of the electrical system of a representative Eastern industrial center.[3]

Diagram I shows the comparative variation of the load for the two largest electrical companies in New York City and for the

[3] The special use of the per cent index plan in the curves of all three of these load diagrams calls for brief explanation. It is chosen as the best means of showing comparative variation of electrical loads. In preparation for plotting, the figure for the average load for the 24-hour period is divided into each of the hourly (Diagrams I and III) or half-hourly (Diagram II) values in the series of data for the particular company or year. The quotients (per cents) thus obtained are plotted above and below a mean axis, which represents unity or the average (the divisor). The value of a unit of the scale is therefore different for each curve and the curves do not show kilowatts. The emphasis is upon relative (per cent) variation from the average instead of upon absolute charges.

The curves are merely a special type of arithmetical curve, being referred to a 100 per cent axis, regardless of the absolute value of the series, instead of to a zero base. Each curve varies above and below its own axis. Ordinary arithmetical curves, if more than two or three in number and representing magnitudes at all diversified, cannot be compared to advantage with reference to their relative variation. The relative range of variation—of which the load factor is a function—is what is significant in the above curves. The eye can readily grasp resemblances and differences in this respect, as it cannot when all these curves are drawn to the same arithmetical scale. If the reader is interested in statistical graphics, he should compare the above Diagram II with the representation of the same facts by curves drawn to a single ordinary arithmetical scale in the Report to the Committee on Gas, Oil and Electric Light (Chicago City Council) on the Investigation of the Commonwealth Edison Co., May, 1913, p. 22. There the relative variations are distorted and made difficult or impossible of comparison.

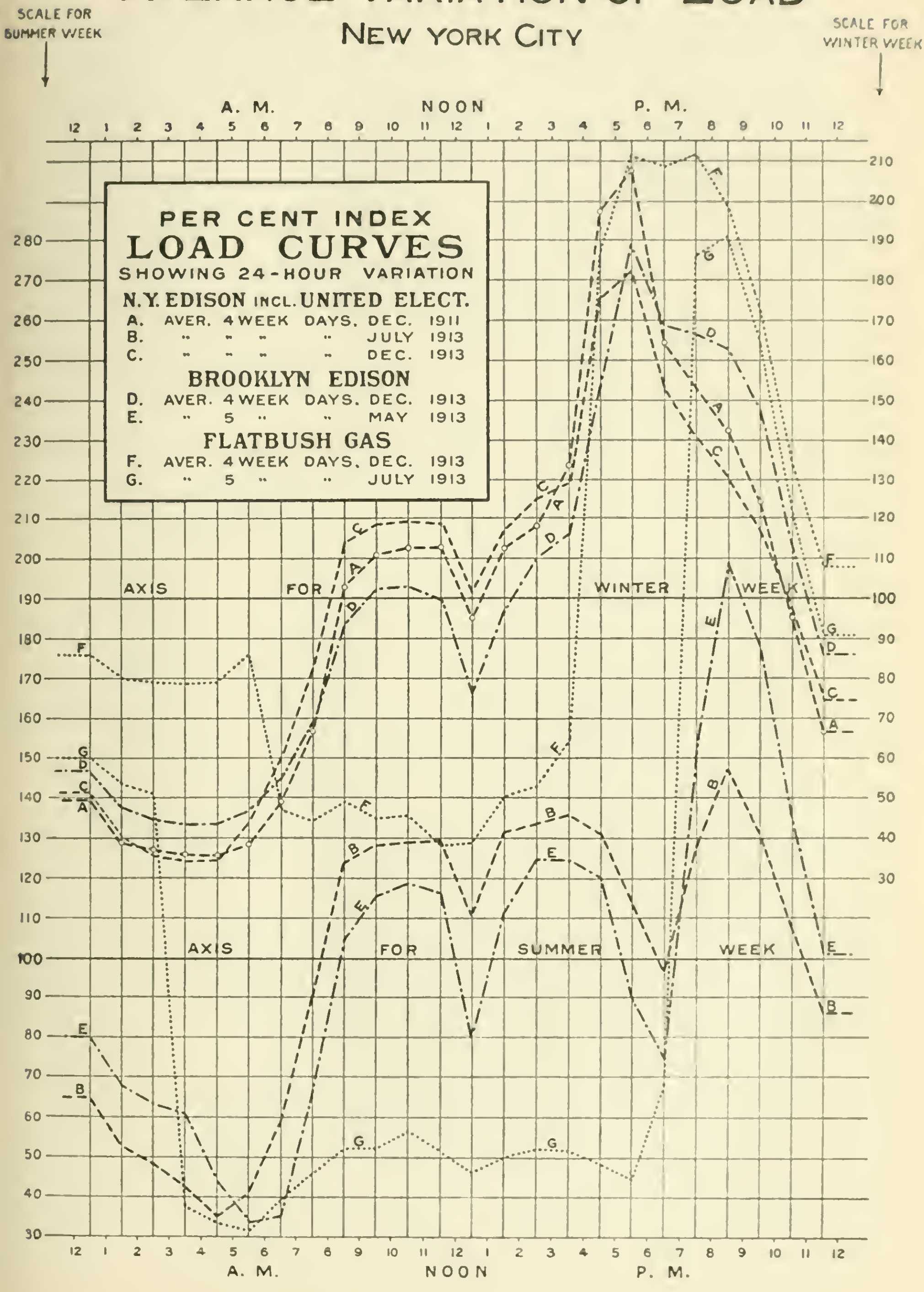
These curves possess in large degree the property that is the special advantage of logarithmic curves in that they express relativity. But they are at the same time more readily understood by the layman who has not enough use for the latter to furnish him with the necessary incentive to learn what they mean. It is important to note that in the per cent index curves the relativity in question applies as between the various curves, but not as between parts (equal intercepts on the ordinates) at different heights of the same curve. In other words, the 10 points between 120 and 130 per cent are not relatively of the same significance as the 10 points between 80 and 90. In a logarithmic curve, on the other hand, there is true relativity as between its parts, so that, for example, the graphic value of the 10 points between 80 and 90 is equal to that of the 15 points between 120 and 135. But the constancy of the representation of equivalent kilowatts for the parts of the same curve is probably an advantage of the per cent index curve used as it is in these two diagrams.

If one were to attempt to draw in the zero bases for the per cent index curves (especially in II and III), the result would be merely confusing. To omit the base would be very bad graphic practice for ordinary arithmetical curves, because in such a case the area between the curve and the base line is primarily significant and the course of the curve is significant only because it shows the development and variation of that area. So far as the same principle applies to these per cent index curves, it is the variation of the area between the curve and the axis that is significant. But where the zero base is equidistant from each of the axes of reference, the effect is much like that for logarithmic curves. In the latter case the zero base is infinitely distant so that the position of the curves in relation to each other can be shifted vertically at will with a view to better comparison.

DIAGRAM I

# SUMMER AND WINTER AVERAGE VARIATION OF LOAD

## NEW YORK CITY



electrical department of a comparatively small gas-electrical company[3] serving an outlying district. Two associated companies are combined in the case of the New York Edison curves because supplied by the same generating stations. For this system, moreover, a 1911 as well as a 1913 curve is given, because of the accession meanwhile of the large Third Ave. street-railway load, the effect of which upon curve C as compared with curve A is interesting.

For present purposes the slightest suggestion of the significance of the differences between these curves is sufficient. The late-afternoon winter peak of the New York Edison is a point that attracts attention. The situation in this respect appears to have been much improved by the added railway load,[4] but is still not certainly better than that of the Brooklyn Edison, despite the heavy daylight load of the former company. On the other hand, the latter company has a relatively more important night and early morning load from street lighting. The Flatbush curves are interesting representatives of the variation of an almost exclusively lighting load, including a considerable proportion of street lighting. High development of the daylight load is the noteworthy feature of the New York Edison summer curve.

The curves of Diagram II are based upon data for a series of eleven years for a single company, namely, the Commonwealth Edison of Chicago, which has shown a remarkably rapid rate of growth. This growth has been brought about largely with direct reference to obtaining the benefits of diversification. The per cent index curves facilitate the comparison of results obtained as ordinary arithmetical curves fail to do. It is hardly necessary to say that the scale is more condensed in Diagram II than in Diagram I, so that the same degree of variation would be represented by flatter

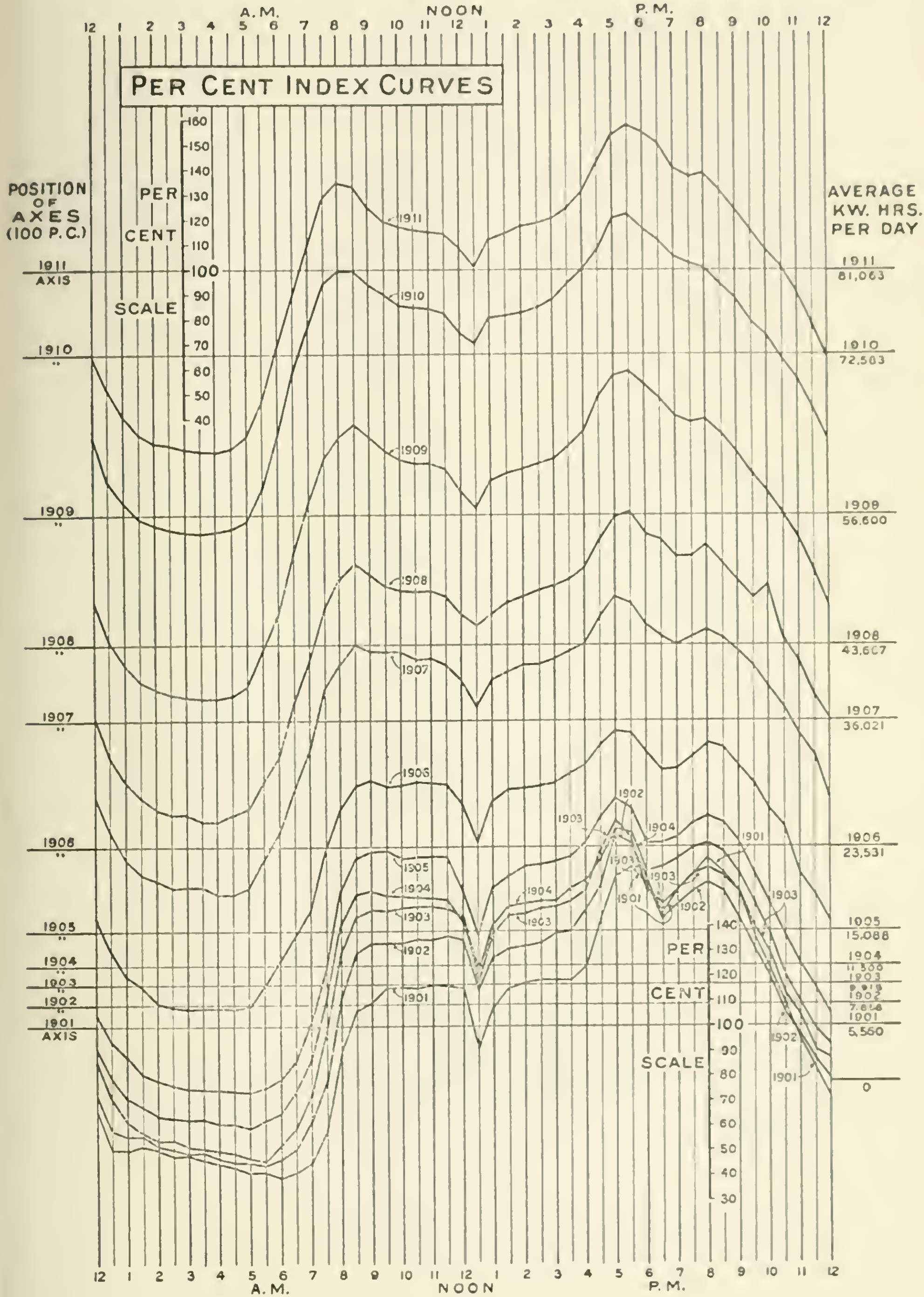
[3] This diagram is also to be found, with accompanying discussion and data, in the 1913 Annual Report of the New York Public Service Commission for the First District, vol. III, p. 72. For purposes of reference in relation to the absolute quantities represented in Diagram I, the following figures of (4 or 5 day) average 24-hour output in kilowatt hours are given: New York Edison, winter, 1911, 1,792,183; 1913, 2,544,733; summer, 1913, 1,681,250; Brooklyn Edison, winter, 527,875; summer, 375,600; Flatbush Gas, winter, 25,883; summer, 13,376.

[4] The demand of the Third Ave. railway system, the accession of which accounts for most of the increase in energy distributed by the New York Edison between 1911 and 1913, in addition to having the usual favorable characteristics of a street railway, is also favorably affected somewhat by the amount of storage-battery operation in this group of companies.

## DIAGRAM II

# AVERAGE 24-HOUR VARIATION OF THE LOAD, 1901-1911

## COMMONWEALTH EDISON CO. OF CHICAGO



curves in the second case.[5] The average day's output for each of the years in the series is shown on the face of the diagram as well as indicated by the arrangement of the axes along an arithmetical scale.

The change in the character of these Chicago load curves has been gradual and not more marked in the later than in the earlier years, although it is during the later years that the increase in energy supplied has been so large. The relative importance of the forenoon load has greatly increased and that of the evening load greatly decreased. In fact the 8 o'clock evening peak has become in effect merely a part of the slope of the late afternoon peak occurring at 5:30. The height of this peak above the axis has remained substantially the same throughout the period under consideration. These figures do not appear to indicate any great improvement in the average diurnal load factor during the ten years. In fact, as computed for 1901 it is 59.8 per cent. and for 1911, 63.3 per cent. The change in the time of the peak is perhaps of the greatest general significance. In 1901 it came at 8 P. M.;[6] in 1911, at 5:30 P. M. In view of the fact that the data are year-round averages, it would appear that the overlapping of lighting for commercial purposes upon power uses during the comparatively few short days must result in a peak much more pronounced than appears in the average values plotted. The evening lighting load should show a nearly constant maximum the year round. The kind of lighting that constituted the peak at the earlier date is now nearly all off-peak, even on the showing of the curves as they stand; and, for the reason just mentioned, at the actual peak season in winter the diversity of this class of business would doubt-

[5] Per cent index variations are properly referred to an axis. While location of the two axes drawn in in Diagram I in relation to each other is merely a matter of graphical convenience, in Diagram II, the relative location of the axes is significant representing, as it does, the comparative magnitude of the load of the Commonwealth Edison Co. in its growth from year to year, and similarly as regards Diagram III.

The three sets of curves are not directly comparable with each other as to their significance in detail because the basic data are different in character, Diagram I exhibiting average variation for a few homogeneous days, excluding Saturdays, Sundays and holidays, and Diagram II, average variation for the whole year, obtained, however, by taking every eighth day instead of every day, while the data of Diagram III are for single days. The data of Diagram II are also for half hourly, instead of hourly, intervals.

[6] The curves are somewhat confusingly mixed at the lower part of the diagram—a defect from the point of view of graphics. But this is preferred either to sacrificing the disposition of the axes along an arithmetical scale or to reducing the range of variation indicated by a given per cent.

less appear more marked.[7] In but few cities, it is true, would this situation be so highly developed or advanced by 1911 as in Chicago.

It appears that the annual load factor greatly improved, having been raised from 29.3 per cent to 43.5.[8] The difference between this comparison and that of diurnal load factors is doubtless due to the fact that the improvement in the variation of demand has been seasonal more than diurnal. In fact the superiority of power is more marked in the latter than in the former respect. This point is not sufficiently emphasized in most load-factor discussions, perhaps because load curves usually represent merely the diurnal variation. The large influence of the taking-over of the street-railway load by the electrical company is a very important element in the latter's improved load factor. Street-railway load factors appear to be in general somewhere around 50 per cent, or at any rate above 40.

Diagram III is on the same general plan as Diagram II and probably fairly represents recent tendencies in the development of the load for large and progressive electrical systems that are in position to obtain and take care of a good deal of industrial business. It differs from Diagram II in showing data for single days instead of averages for many days. It also relates to the December peak condition instead of to the average for the year. It is therefore not affected by the different character of the curve in summer, as the averages used in Diagram II are. Thus it shows conditions only at the critical time when loads are heavier and peaks greater. The day of maximum output is considered rather more representative of conditions than the day of the highest peak, though, of course, the two are often identical.

The general technique of construction and the use of per cent index curves is the same as in Diagram II, but the variation of the load is shown by hourly instead of half-hourly intervals. The axes are arranged according to the scale of the kilowatt-hour output on the December days in question. The result is not essentially different from what it would be if the axes were arranged according to

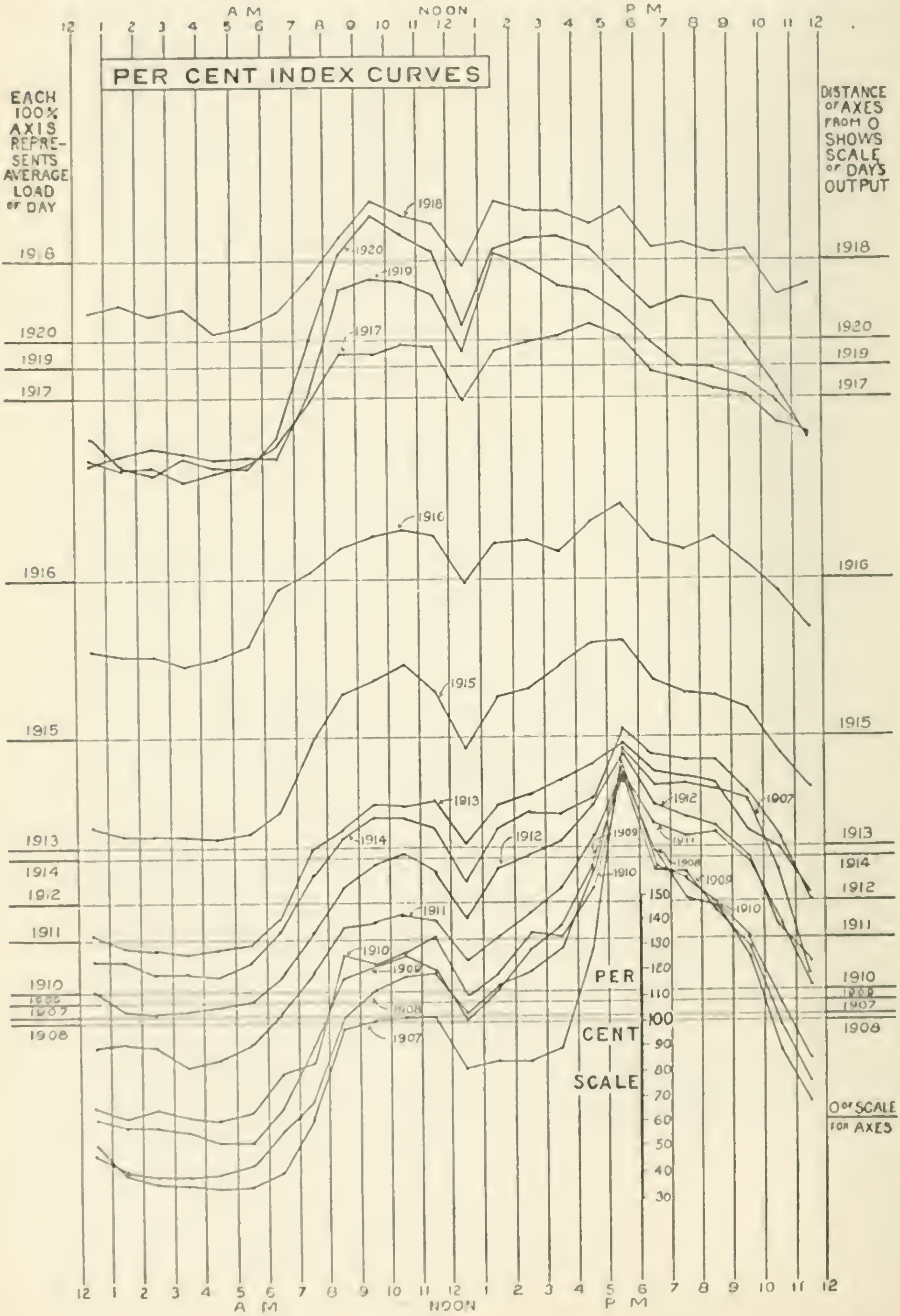
[7] Cf. the New York Edison curve for December, 1911, in the diagram on page 17, above. The same company's 1913 curve is much improved by its having meanwhile taken on the Third Avenue street railway system.

[8] Chicago Report, p. 22. In the diagram there shown annual load-factor per cents are put alongside arithmetical diurnal curves in a way that conveys a wrong impression.

DIAGRAM III

# VARIATION OF THE LOAD ON DECEMBER MAXIMUM OUTPUT DAYS, 1907—1920

## ELECTRICAL SYSTEM OF A LARGE EASTERN INDUSTRIAL CENTER



the scale of yearly outputs, and the method used has some advantages. But it is significant that the yearly output has in fact, on the whole, increased somewhat more since 1912 (the period for which such data are at hand) than the December maximum day's output, which fact indicates a gain in evenness of seasonal distribution as well as in December daily load factor.

This diagram brings down to date the comparisons made in previous diagrams. In the character of the development shown, even more than in the period covered, these curves doubtless overlap the development at Chicago, because the Chicago company was a pioneer in this kind of expansion. But the company to which the data of Diagram III relate has probably made more use of industrial opportunities than some. Indeed, similar possibilities are not open to companies serving the smaller population and industrial centers. It is worth noting that the 1919 curve shows a degree of reaction due to the decline of some war activities. The company does not supply power to the local street-railway system, though it does serve one interurban railway of relatively small importance.

The marked improvement in the December load curve in the 13 years covered speaks for itself. The daily load factor on the hour-interval basis for the December day used may be computed at 48 in 1907 as compared with 63 in 1912, and 88 in 1920. The greater the industrial demand, also, the earlier in the day comes the peak. The industrial and similar demand accounted for roughly one-half of the total output of the year in 1912 and for two-thirds in 1920. Annual load factors on the hour-interval basis were 45 in 1912 and 56 in 1920.

In this connection it is worth mentioning that some of the large hydro-electric plants have achieved load factors above 80 per cent.[9] Comparable with a 1916 load factor of 43.20 for the great Chicago company are the following figures for certain other urban supply systems: N. Y. Edison and United Electric 38.30 (but the basis is not correct unless the New York & Queens Electric L. & P. peak is included); Public Service Electric of New Jersey, 39.82; Detroit Edison, 47.80; Philadelphia Electric, 35.6; Cleveland

[9] Below is a table showing yearly load factors in per cent transcribed from the issue of the Electrical World for March 29, 1919, page 633. The Commonwealth Edison's load factor for 1916 is given as 43.20, presumably on a slightly different basis from that used in the previous reference in the text.

Electric Illg., 45.8; Edison of Boston, 33.72; Edison of Brooklyn, 38.1. The proportion of railway load and of power for manufac-

LOAD FACTORS OF THE LARGEST GENERATING SYSTEMS IN AMERICA

(Includes all companies in the United States and Canada having yearly outputs in excess of 100,000,000 kilowatt hours; arranged in order of output in 1918.)

| System | 1916 | 1917 | 1918 Date of peak | 1918 Load factor |
|---|---|---|---|---|
| Niagara Falls Power | 80.64 | 88.97 | Apr. 8 | 92 2 |
| Ontario Power | 86 80 | 91.5 | Dec. 13 | 81.9 |
| Commonwealth Edison of Chicago | 43.20 | 44 6 | Dec. 2 | 43.6 |
| Montana Power | 84.50 | 73.0 | Nov. 21 | .... |
| Shawinegan Water & Power | 50.00 | 60 4 | Sept. 24 | .... |
| Montreal L. H. & P. | .... | 70.8 | Dec. 6 | 68.0 |
| N. Y. Edison & United Electric | 38.30 | 39.2 | Dec. 11 | 38.2 |
| Pacific Gas & Electric | 62.20 | 61.6 | June 4 | 63.1 |
| Toronto Power | 58.40 | 84.0 | Dec. 3 | 81.9 |
| Public Service Electric | 39.82 | 46.2 | Dec. 5 | 48.9 |
| Detroit Edison | 47.80 | 50.4 | Dec. 13 | 51.3 |
| Southern California Edison | 56.04 | 54.4 | July 12 | 54.5 |
| Philadelphia Electric | 35.60 | 46.0 | Dec. 6 | 47.6 |
| Duquesne Electric | 52.30 | 54.0 | Dec. 6 | 51.9 |
| Buffalo General Electric | 57.00 | 52.7 | Nov. 22 | 64.4 |
| Mississippi River Power Co. | 54.30 | 63.0 | Mar. 8 | 61.8 |
| Cleveland Elect. Illg. | 45.80 | 45.0 | Nov. 22 | 48.33 |
| Utah Power & Light | 67.80 | 72.5 | Dec. 27 | 74.83 |
| Tennessee Power | 67.00 | 73.41 | Dec. 11 | 67.6 |
| Pennsylvania Water & Power | 61.80 | 68.6 | Feb. .. | 64.2 |
| Great Western Power | 62.65 | 71.13 | Aug. 12 | 68.0 |
| Consol. G. El. L. & P. of Baltimore | 59.10 | 62.4 | Nov. 7 | 64.9 |
| Puget Sound Tract. L. & P. | 51.80 | 54.0 | Dec. 20 | 65.4 |
| Consumers Power Co. | .... | 46.0 | Nov. 21 | 46.8 |
| Elec. Co. of Mo. & Union Elec. L. & Pr. | 43.10 | 46.5 | Nov. 26 | 49.1 |
| Alabama Pr. | 51.07 | 56.7 | Dec. 19 | 51.5 |
| Wisconsin Edison and Milwaukee El. Ry. & Lt. | 39.00 | 44.0 | Nov. 20 | 43.0 |
| New England Power | 44.00 | 48.0 | Dec. 16 | 48.0 |
| Minneapolis General Electric | 44.90 | 46.16 | Nov. 1 | 53.3 |
| Edison Elect. Illg. of Boston | 33.72 | 36.1 | Dec. 6 | 35.0 |
| Brooklyn Edison | 38.10 | 37.5 | Dec. 11 | 37.5 |
| Portland Ry. L. & P. | 46.50 | 49.0 | Dec. 23 | 52.0 |
| Sierra & San Francisco Pr. | .... | 49.44 | July 16 | 53.7 |
| Georgia Ry. & Power | .... | .... | Nov. 8 | .... |
| Michigan Northern Power | 74.40 | 76.7 | Dec. 24 | 79.4 |
| Rochester Ry. & Lt. | 41 00 | 44.0 | Nov. 22 | 42 8 |
| Washington Water Power | 60.80 | 58.5 | Nov. 26 | 65.1 |
| Great Northern Power | 48.80 | 51.5 | ....... | 44.9 |
| Adirondack Electric Power | 41.40 | 43.1 | Nov. 8 & Jan. 23 | 39.6 |
| Potomac Elect. Power | 36.10 | 36.09 | Dec. 20 | 41.0 |
| Virginia Ry. & Power | 44.54 | 47 39 | Dec. 18 | 52 8 |
| Southern Sierras Pr. & Nevada California Power | 66 50 | 65.3 | Aug. 6 | 65.3 |
| Toledo Ry. & Lt. | 42.20 | 49 4 | Dec. 4 | 45.7 |
| Southwestern Pr. & Lt. | 43.00 | 46.0 | Sept 26 | 44 5 |
| Empire District Elect. | 49.70 | 52.4 | Sept. 5 | 51.4 |
| Southern Power | .... | .... | ....... | .... |

turing has most to do with the differences. A company with a large proportion of hydraulic prime-movers, also, will usually have rates that especially encourage industrial and off-peak uses and will be likely to have a correspondingly high load factor.

It should be noted that in the three diagrams above presented the peaks and depressions are smoothed-out somewhat by the character of the data (average kilowatts for considerable intervals) and the method of construction (oblique straight lines between the average points). On the other hand, the deleterious effects of an overload upon generators, etc., are not immediate, hence a time-lag in the response of the curves to changes in the load is not inappropriate.

As will appear in the following chapters, the load factor is essentially an economic rather than a technological matter. The output of an electrical company is obviously determined by the needs and wishes of its consumers. Its maximum output is also determined by its consumers. It is the business of the company to be ready with the supply when it is wanted. If an electrical company seeks to increase its load factor, it must operate through the motives and habits of actual and possible consumers, in other words, not through internal organization and management, but through selling policies and rate schedules.[10]

It is worth noting that the date of the maximum within the year has an effect upon the computed load factor in the case of a rapidly growing company. Allowance for this can be made, when data for successive years are at hand, by reducing the maximum (or increasing it, if it occurs near the beginning of the year) in the ratio of the elapsed time after the middle of the year to the time (approximately one year) between the two maxima respectively within or closest to the year for which the average kilowatt hours are taken.

[10] Too exclusive attention to diurnal variation is doubtless responsible for a misapplication of load-factor principles in connection with gas rates. Where the gas holders will contain nearly or approximately one day's supply, which is the usual situation, it is obvious that the operations of the company are but little affected by the time of day when most gas is consumed, or whether 10 per cent or 30 per cent of the day's consumption is taken between 5 and 7 P. M. The seasonal variation, on the other hand, as between the highest and the lowest monthly average per day, will be decisive in determining the necessary investment in production plant. Hence, if gas companies were to adopt load-factor rates, the reference should be to the seasonal, not to the diurnal, variation, and the maximum demand should be determined by the greatest average use per hour during a day or even longer period. But load factor principles have been applied by the Consolidated Gas Electric Light & Power Co. of Baltimore in its gas rates for industrial uses (Hopkinson type) on the basis of the greatest number of *cubic feet used in any one hour* (6 Rate Research 372), and for domestic use (Wright type) on the room basis. The latter is practically a density-factor rate. For the first class the rate is further qualified with reference to diversity as follows: "For installations in which the use of gas is considerably less between the hours of 5 P. M. and 7 P. M., during the period from October 1st to the succeeding March 1st, in each year, than at other times, the specified demand upon which the rate is based may be taken as

### Further Matters of Economic Technology

The central-station industry is or should be an object of study especially interesting to those who are concerned with technological economics, not only because of the load factor, but also because of the unusual importance in this connection of the so-called principle of "increasing returns," otherwise referred to as "the economy of large-scale production," "the density factor," etc.

The highly capitalistic character of electricity supply has already been mentioned. The fixed investment per unit of service and per employee is probably not exceeded in any important branch of industry. It suffices for present purposes to make the statement thus qualifiedly, and it is not possible to do much better. The fixed-capital accounts of large and successful enterprises are not of so determinate significance as to make comparisons on that basis certainly worth while, and satisfactory "physical" valuations for various classes of corporations are not as yet comprehensive enough to afford the facilities for an adequate statistical study by such means. The significance of the great proportion of fixed capital cost in the total cost of electricity supply will appear in various connections in the succeeding chapters.

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the measured rate of use occurring during any hour between the said hours in the said winter months; provided that the demand shall in no event be taken as less than one-half of the maximum measured rate of use at any other time, the use under such conditions being classed as non-peak." (Schedule K, describing the rates referred to, is printed in full in the Report of the Differential Rates Committee of the National Commercial Gas Association for 1917.) It should be noted that the demand is specified in the contract, subject to revision upon measurement. Moreover, the company may at its option give permission to exceed the determined maximum rate of use. It is probable that the intent of such rates is concerned with the density factor at least as much as with the load-factor, and the effect may be substantially that of quantity-block discounts. The schedule in question was accepted by the Maryland Commission. A gas rate accepted by the Illinois Commission also provides for a demand element based on a 30-minute or (optionally) a 5-minute interval (9 Rate Research 295-6).

The fact that the Baltimore company distributes by-product gas has an evident bearing upon its interest in stimulating the demands of large consumers. It is not apparent how this fact would affect particularly the hours of the day within which the gas might best be supplied.

It would doubtless be possible to work out a reasonable scheme of customer, output, and capacity costs and charges for a gas utility. The distinctiveness and importance of the first element in cost cannot be gainsaid. It is also true that cost analysis will easily identify the last of the three elements. But this is true of any branch of manufacture employing considerable fixed capital. And as to the method of distributing the manufacturer's fixed cost or passing it on to consumers, the straight rate per unit of output, modified by quantity discounts, is the one generally indicated. The heavy loading of a gas plant depends more upon quantity taken than upon time of day. One might, reasoning from this one ground, conclude (contrary to fact) that quantity discounts will be in practice more important in the gas than in the electrical field. A quantity-block rate varying per unit of meter capacity (that is, per light), supported by well-considered rules as to meter installation, would meet the requirements of the gas supply situation better than a true load factor rate

The large and lately much increased size of electric generating units is another significant fact for the economist. Turbo-units of 30,000 kilowatts, and larger, capacity are getting to be commonplace.[11] In 1881 the so-called "jumbo" Edison dynamo had a

[11] The report of the 1919 N. E. L. A. Committee on Prime Movers (Convention proceedings, Technical volume, pp. 16-17) contains a summary of Large-Unit Installations, as of May 1, 1919, from which the following is drawn. Some of these are transporation companies. With cross-compound machines having two and three prime movers and generators, the complete machine is considered as a unit.

| | Capacity of largest unit | | Per cent of total capacity in 20,000 kva. and larger units |
|---|---|---|---|
| | Kva. | Per cent of total | |
| Buffalo General Electric | 38,889 | 30.8 | 100.0 |
| Consolidated Gas Elec. L. & P. (Baltimore) | 20,000 | 24.5 | 49.1 |
| Boston Elevated Railway | 35,000 | 28.5 | 28.5 |
| Edison Elec. Illg. (Boston) | 30,000 | 21.0 | 21.0 |
| Alabama Pr. (Birmingham) | 33,333 | 23.1 | 41.6 |
| Edison Elec. Illg. (Brooklyn) | 30,000 | 24.7 | 42.8 |
| Brooklyn Rapid Transit | 30,000 | 21.5 | 30.6 |
| Commonwealth Edison (Chicago) | 35,300 | 7.1 | 45.7 |
| Cleveland Elec. Illg. | 31,250 | 15.0 | 72.1 |
| Union Gas & Elec. (Cincinnati) | 25,000 | 29.0 | 50.3 |
| Northern Ohio Traction (Cuyahoga Falls) | 22,222 | 33.2 | 60.3 |
| Detroit Edison | 45,000 | 23.3 | 54.4 |
| Pennsylvania R. R. (Long Island City) | 21,100 | 27.1 | 52.7 |
| Twin City Rapid Transit (Minneapolis) | 20,000 | 30.8 | 30.8 |
| Moline Rock Is. Mfg. | 20,000 | 39.6 | 39.6 |
| Interborough Rapid Transit (New York City) | 70,000 | 18.0 | 65.8 |
| New York Edison | 30,000 | 10.5 | 38.8 |
| Public Service Elec. (Newark) | 35,000 | 13.2 | 39.6 |
| United Elec. Lt. & Power (New York City) | 25,900 | 20.7 | 52.8 |
| Philadelphia Elec. | 35,000 | 12.5 | 55.0 |
| Narragansett Elec. Ltg. (Providence) | 47,500 | 55.5 | 78.9 |
| Duquesne Lt. (Pittsburgh) | 47,200 | 28.1 | 28.1 |
| N. Y. Central R. R. (Port Morris & Yonkers) | 20,000 | 33.3 | 33.3 |
| Reading Transit & Lt. | 25,000 | 100.0 | 100.0 |
| Union Elec. Lt. & Power (St. Louis) | 25,000 | 30.1 | 30.1 |
| United Elec. (Springfield, Mass.) | 20,000 | 44.4 | 44.4 |
| Toledo Ry. & Lt. | 23,500 | 26.7 | 52.0 |
| Worcester Elec. Lt. | 20,000 | 46.5 | 46.5 |
| Wheeling Elec. (Windsor, W. Va.) | 30,000 | 43.5 | 87.0 |

The ratios show the extent to which reliance is placed on a single machine.

To the above list should be added, as having generators of 30,000 kilowatts or more in place or ordered by the end of 1920, the Niagara Falls Power Co., the Hydroelectric Commission of Ontario, the Pacific Gas and Electric, and probably others. Moreover, further large machines have been ordered by a number of the companies above listed.

In an article in the Electrical World for Jan. 17, 1920, page 132, Mr. F. D. Newberry, of the Westinghouse Electric and Manufacturing Co., sums up the development of large generating units as follows: Before 1912 the largest unit was of 8000 kilowatts capacity. In the five years 1914-1918 units of 20,000, 25,000, and 30,000 kilowatts became as common as units of 5000 and 10,000 kilowatts had been during the preceding five years. In the last two years there has been a noticeable slowing up in the increase in the size of units. Few single-shaft units larger than 30,000 kilowatts have been purchased.

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capacity of 100 kilowatts; and in 1898 the largest generator built or building was of 4600 kilowatts.[12] In contrast with the stations of several hundred thousand kilowatts capacity, there are now in operation, at the other extreme, numerous small stations with generators of 100 kilowatts and less.

The economic significance of the above comparisons depends upon the relation of cost of energy to the size of the generator. In a recent scientific discussion of this subject,[13] a general rule as regards original cost of apparatus has been formulated as follows: "If the speed remains constant the cost per kilowatt will decrease by approximately 65 per cent for an increase of 10-fold in the size of the unit." As to operation, the same authority says, "Operating costs increase with decrease in size much faster than do fixed charges."[14] We are not here concerned with the scientific exactness or the extent of applicability of such a formula. Even if rather rough, it serves emphatically to point the moral of the great importance of large-scale production in the electrical industry. It should be noted, moreover, that it is not safe to depend upon a single generator for too large a fraction of the total demand, hence large generators are not available for the small stations so much as may appear.[15] Comparison of the capacity of such large-size generators as those above mentioned with that of various classes of power plants are interesting in this connection.

The Wisconsin Commission[16] publishes statistical data as of 1916 for 185 central-stations enterprises. The largest one has a capacity of 44,030 kilowatts; the next largest 15,500 kilowatts; 6 others have capacities of more than 5000 kilowatts; 18 have capacities of as much as 1000 but not as much as 5000. Of the remaining 159 stations only 17 have 500 kilowatts or more capacity.

[12] Paul M. Lincoln in Presidential Address, 1915, A. I. E. E. Proceedings, page 1495. Cf. also the development in sizes of generator units for the Commonwealth Edison Co., of Chicago, as reported by Mr. Insull in the Journal of the American Society of Mechanical Engineers, Nov. 16, 1916, page 847: In 1887, 160 kw.; in 1902, 3500; in 1903, 5000; in 1915, 35,000. The Commonwealth Edison was a pioneer in this development, but has lately been surpassed by others.

[13] Paul M. Lincoln, Relation of plant size to power cost, 1913 A. I. E. E. Proceedings, page 1936.

[14] Page 1941.

[15] Difficulties to be met in intrusting one fourth of the load to a single machine are discussed in the report of the 1919 N. E. L. A. Committee on Prime Movers. Compare this with the ratios of the second column of the table in the footnote at page 27, above.

[16] Tenth Annual Report of the Railroad Commission of Wisconsin (year ended June 30, 1916), pages 575, 585, 593, 598-601, 606-609.

The New York Second District Commission, which has jurisdiction outside New York City,[17] publishes data including station capacity for 122 central station enterprises. Of this total 12 have capacities of 5000 kilowatts but less than 20,000; and 9 have capacities of 20,000 or more. Of the remaining 101, 46 have capacities under 500, 18 from 500 to 999, and 37 from 1000 to 4999.

In Illinois, where combination should be expected to have more effect on the size of electric power plants than in most states, of 100 public-utility plants reporting in 1916,[18] 59 had a "maximum" capacity of less than 500 kilowatts and 34 others had a capacity of less than 10,000, leaving 7 of larger capacities.

It is evident that, from an engineering viewpoint, most electrical plants operated as central stations, or performing a public service, are small plants, comparable with isolated plants as to conditions and methods of operation rather than with the big alternating-current generating stations that send electricity over miles of high-tension cables to numerous substations from which, through the distribution system, consumers are supplied. The tendency to centralization in electricity supply means the displacement of small generating plants by more or less distant sources of supply. Whether the small plants are operating as central stations with a small distribution system supplying their immediate neighborhood is not of much technological significance. How far the process of centralization may go depends, of course, upon the economies of large-scale "production"—which are conspicuous in the case of electric generation—and upon the cost of transmission. As to the latter cost, whatever it may be absolutely, the possibilities of meeting it depend upon *density* of demand.

In considering large-scale production, it is necessary to have clear ideas as to the significance of "density." In general, the greater the amount of productive capacity, of both capital and labor, that can be applied economically at a given place, with concentration of management and unity of organization, the smaller will be the unit cost for the resulting enlarged output. This fact is obviously true for manufactures generally and is commonly

[17] Annual Report for 1917 (year ended December 31), vol. IV, pages 66, 126, 181, 206, 218.

[18] Illinois Public Utilities Commission Statistical Report for the year ended June 30, 1916, page 795 ff.

referred to as the "advantage of large scale production." It is true for the railroads, where it is referred to as the tendency to "increasing returns," that is, increasing profits under the same rates, resulting from the growth of traffic on a given line. In this case, since the service cannot be disconnected from the plant and sent to the consumers, traffic must grow up adjacent to the plant in order that density may develop. The situation as regards electricity supply is similar to the second case in that the service has to be rendered in connection with the distribution system. As regards the size of the electric power plant, on the other hand, the situation resembles that of a manufacturing enterprise, but the electrical power-maker must supply his own "transportation" system. The relation between the load factor and the density factor has been discussed by the writer in another connection.[8]

Since the capacity of generators and other electrical equipment plays so large a part in the economics of electrical enterprises, it is worth while in this connection to devote a few words to the subject of rating. Standard rating is "continuous rating," that is, rating according to potentiality for steady and uninterrupted output at highest efficiency for an indefinite period. In general it is the decline of efficiency, occurring when the capacity of a machine is forced, that limits the rating. For electrical apparatus, however, the tendency to an injurious rise of temperature is the limiting factor. But if the excess load is only momentary or is not continued for a considerable time, any temperature rise, which is by nature cumulative, is soon counteracted and no harm results.

In other words, an electric generator ordinarily has considerable overload capacity. This fact has an important bearing on the significance of the load factor. The peak that is of fundamental technological and economic significance is the highest average demand for an *interval* of time, perhaps 30 minutes, or more or less, not the highest instantaneous demand. It is commonly the practice of manufacturers of electrical equipment to guarantee certain overload capacities for limited periods under specified conditions.

If the relation of the overload capacity to the continuous rating of a generator varies, the economic significance of the latter is

[8] Article in the American Economic Review for December, 1915, entitled, A Third Factor in the Variation of Productivity: The Load Factor, page 758, especially the first section.

evidently subject to some qualification. It is possible that recent developments in the construction of large generator units tend to cause the absorption of some former overload capacity in the continuous rating. The newer turbo-units are built with reference to easy ventilation and rapid cooling. The continuous rating thus in effect absorbs some of what would otherwise be overload capacity and the relative overload capacity is correspondingly reduced. In the case of a company with quickly rising and receding peak demands, it may therefore be necessary to have a larger reserve capacity. On the other hand, the elasticity of the carrying capacity of turbo-units and the development of devices for the rapid raising of steam on demand ought to mean greater facility in dealing with peaks, such as might make it possible to dispense with some of the reserve capacity formerly needed to meet such demands. In one way this increased operating elasticity of generators—the fact that their efficiency does not vary greatly within a wide range of loading—tends to put the moderate-sized central station more nearly on an equality with the large one, since fewer and larger generators can be used if it is less necessary to provide for varying the capacity in use by switching in or out additional machines. In the matter of reserve capacity, an electrical company often finds it economical to keep in operating condition for standby and supplementary service some of its obsolete and otherwise superseded equipment. Where certain machines are required to be used only 90 hours a year, a very low degree of operating efficiency can easily be counterbalanced by the increase in fixed charges for up-to-date equipment.

It is said that American plants tend to utilize overload capacity in dealing with peak demands to an extent unknown in foreign practice. But the fact may rather be that American manufacturers of generators have in the past been inclined sometimes in effect to increase the overload capacity by understating the regular rating. It appears, at any rate, that the standard American rating practice would ordinarily assign to a generator a somewhat lower rating than European standards. This general situation serves to remind one that it is not merely in the field of the social sciences that basic statistical quantities are approximate rather than exact.

A. C. turbo-units are most accurately rated in kilovolt amperes. Not only is this unit somewhat different from the kilowatt, but its

relation to the latter is somewhat variable. The nature of the difference is indicated in the definition of the power factor given above.[20] What the matter amounts to practically may best be illustrated to the non-technical reader by way of a somewhat stretched analogy with the conditions of water distribution. If the utilization of water from a system of mains required that the water be kept in motion past a given point of consumption at about a given rate, then the water would be distributed through "circuits" providing for a return current to the central source of supply. And if only a certain percentage (say 80 per cent) of the water coming to the service pipe of a consumer could be obtained by him, then the amount of water kept circulating through the distribution system would have to be one-fourth greater than would be necessary if the consumer could take 100 per cent. Pipes and pumps would also have to be correspondingly greater. This is about the situation when the power factor enters into consideration in electrical supply. Generators and other apparatus have to be larger (in the ratio to the power factor of its complement) than would otherwise be necessary. That is, for a power factor of 80, equipment must be of 20/80ths, or one-fourth, greater capacity than for a 100 per cent power factor. The power factor relates to alternating-current equipment and the figure varies according to whether machines are under light load or full load.[21]

There appears to be a substantial consensus of opinion among central station men that the power factor is not a rate problem, though an extra charge or penalty for a power factor below 80 is considered a suitable means of regulating the installations and practices of consumers. A considerable number of companies have recently specified in their power rates a standard power factor and included a scale of surcharges for low power factors.[22]

There are various differences between alternating-current and direct-current distributing systems that are of much economic as well as technological importance. The use of the one or the other system in a particular district is due to historical developments as

[20] Note on page 13.

[21] Methods of measuring the power factor, or estimating it, for use as a rate element, are discussed by Will Brown in the Electrical World for Dec. 28, 1918, pages 1220-22. Usually attempts are made to regulate the power factor directly, instead of charging for low power factors.

[22] A count of the 1920 N. E. L. A. Rate Book shows 23 companies with power-factor penalty clauses.

well as to the requirements of present economic and physical technique. Even if it were possible, however, for the writer to deal successfully with the differences in question with due regard to the numerous engineering principles and problems involved, there is no necessity for that in the present connection. Whether the energy delivered is alternating-current or direct-current should not be allowed to affect comparative rates except under some such conditions as the following. If the central-station company is in position to give consumers an option as to which form of electric energy they will take, then the company may be permitted to charge more for one than for the other, in conformity with any experienced difference in cost. Or if any considerable number of consumers, on good grounds, prefer one to the other, then the company may be allowed to make the supply conditional upon an extra charge for the extra costs incurred by reason of such preferences.

One of the most important developments in the electric-supply industry of recent years—a development much stimulated by the War—is the interconnection of generating plants. This is done partly as insurance, in order to make immediately available new supplies of electric energy upon the breakdown of a station; partly for the sake of operating economy, to make possible the substitution of purchased energy for low-load periods (especially for the smaller or older plants), thus involving load-factor considerations and the preferential and intensive use of large generating units; and, finally, in part with direct reference to taking advantage of diversity, through exchange of energy, so as to reduce peaks and load factors. In New England and on the Pacific Slope, the idea has been practically applied over considerable areas. Extensive further projects are being discussed. One proposal is to make transmission systems common carriers under the law in order to promote the development. There are said to be no insuperable engineering difficulties in the way of tying together the whole industrial area of the North Atlantic states. A further step would be generation (so far as from coal) at the pit's mouth. Comprehensive developments of this nature, however, would encounter difficulties in obtaining adequate water supplies for condensation. Of course any plan of interconnection includes hydro-electric plants at considerable distances from consuming centers.

## The Development and Importance of Electricity Supply

Central-station electric supply as a business enterprise dates from about 1880, arc lighting in this country having been initiated a little earlier, while incandescent lighting came a year or two later. Substantially its entire history therefore comes within the life of the present generation.

The United States Census of Central Electric Light and Power Stations provides material indicative of the present and prospective importance of the industry. The following data are for commercial and municipal stations combined,[23] the latter class being a relatively unimportant contributor to the total:

| Year | Total income (1000's of dollars) | Kilowatt rating of generators | Output of stations (1000's of kw. hrs.) |
|---|---|---|---|
| 1902 | 85,701 | 1,212,235 | 2,507,051 |
| 1907 | 175,642 | 2,709,225 | 5,862,277 |
| 1912 | 302,273 | 5,165,439 | 11,569,110 |
| 10-year per cent increase | *252.7* | *326.1* | *361.5* |
| 1917 | 526,894 | 8,994,407 | 25,438,303 |
| 10-year per cent increase | *200.0* | *232.0* | *333.9* |

The rate of growth and the present magnitude of the central-station industry speak for themselves. But these figures relate only to electricity supply as a separate public-service enterprise. To the output for 1917 above given may be added 7,240,503 thousands of kilowatt hours for energy generated by the power plants of electric railways and 561,784 thousands for electrified divisions of steam roads, etc.,[24] for which the economic technology of the generation and use of electric current is much the same as for central stations. Indeed there is a tendency towards the operation of traction systems with central-station power, which thus makes the terms and conditions of their supply a part of the electrical rate problem. There remains the numerous private or isolated plants in factories, office buildings, etc., similarly to be considered in this connection. The aggregate output of such plants is of course unknown, but it appears to be comparable in magnitude to the central-station product.[25]

[23] Central Electric Light and Power Stations and Street and Electric Railways, 1912 (published, 1915), p. 20, Table 5; Central Electric Light and Power Stations, 1917, p. 23, Table 8.

[24] Page 38, Table 31, of the Census of Electrical Industries, 1917: Electric Railways.

[25] *Cf.* p. 168 ff., below.

The growth of the hydro-electric element in the total capacity of central stations is of no less permanent economic importance, though of comparatively incidental interest in the present connection. This development involves corresponding progress in the technique of electrical transmission. Measured on the basis of output the importance of water power in comparison with other sources would be shown considerable greater.

| Year | Horse power of prime movers— Other than hydroelectric | Hydroelectric | Total |
|---|---|---|---|
| 1902 | 1,400,576 | 438,472 | 1,845,048 |
| 1907 | 2,749,101 | 1,349,087 | 4,098,188 |
| 1912 | 5,060,813 | 2,469,231 | 7,530,044 |
| 1917 | 8,659,482 | 4,277,273 | 12,936,755 |

At to the comparative rate of growth of the electric supply industry, it is hardly necessary to say that no other class of public utilities and practically no other branch of industry shows for the available 10-year comparison a comparable relative increase. Railroad freight car mileage, which happens to be the available index that can be carried back most satisfactorily from a recent date, increased from 14,194 millions in 1903 to 21,035 millions in 1913, or 48 per cent for the decade.[26]

The greatest rates of increase shown by any of the most important branches of manufacture in the United States for the decade 1904-1914 were for automobiles with a 1788 per cent increase in the value of products and automobile bodies and parts with a 3724 per cent increase. Industries or groups with value of products exceeding $100,000,000 in 1914 numbered 56. Electrical machinery, apparatus and supplies, with a 138 per cent increase, is conspicuous among these. Indeed, besides automobiles and automobile parts, only food products (259 per cent), rubber goods (255 per cent), cement (240 per cent) and fertilizers (171 per cent) exceed it. For all industries the 10-year increase in the value of products was 64 per cent. These ratios are comparable with a 10-year increase for central stations of 253 per cent in "income" and 361 per cent in output. The direct comparison of value of products as between the various branches of manufacture and electricity supply is hardly fair to the latter, however, because electrical

[26] Interstate Commerce Commission: Statistics of Railways in the United States, 1913, p. 46.

rates have been going down decidedly while the census decade was one of a very considerable rise in prices for most products. It is safe to say that electricity supply has had a rate of growth that puts it in a class by itself among important industries, with the one exception indicated.[27]

Such comparisons of rates of increase need to be supplemented by comparisons of absolute magnitudes. The total earnings of central stations in the United States in 1912 (calendar year) were 302 million dollars and in 1917, 527 million. In 1913 (fiscal year) the railroads of the country earned 3125 million dollars,[28] or ten times as much. But in 1888, the year of the first statistical report of the Interstate Commerce Commission, the railroads earned only 911 million dollars.[29] At that date they had back of them twice the length of years electricity supply had in 1912. As to comparative valuation of property, the latest available United States Census data[30] show estimates as of 1912 of 16,149 million dollars for railroads and their equipment and 2099 million dollars for privately owned central electric light and power stations.

The comparison of income and output as shown above at page 34 gives the following averages per kilowatt hour: In 1902, 3.52 cents; 1907, 3.00; 1912, 2.61; 1917, 2.07. These results are not good average prices, since doubtless something besides revenues from sales is included in income and the output figures include duplication from inter-company sales as well as losses. But it is a fair conclusion that average prices declined by more than one-fourth between 1902 and 1912 and by nearly one-third between 1907 and 1917. Maximum prices available to small consumers may have declined nearly as much. The results indicate at least the strongly dynamic condition of the industry.

As to costs of construction and equipment—which are now subject to large allowance for price changes affecting metals especially, due to the War—it appears that generators cost 20 cents per watt in 1882, 2 cents per watt in 1898, and less than ½ a cent in 1915.[31]

[27] Data from Abstract of the Census of Manufactures, 1914, pages 26-7.

[28] Statistics of Railways, 1913, p. 48.

[29] Statistics of Railways, 1888, p. 17.

[30] U. S. Bureau of the Census: Estimated Valuation of National Wealth, 1850-1912 (dated 1915), Table 2, p. 15.

[31] Paul M. Lincoln, in 1915, A. I. E. E. Proceedings, page 1496.

### The Problem Confronting Regulating Bodies

The present work deals with the economics of rate-making, not with the legal and administrative aspects of the problem. When the decision or opinion in a case before a court or a commission is here cited, it is not with reference to establishing a legal rule, nor to forecasting an administrative policy. The legal situation should progressively conform to the requirements of economic fact and principle. But the existing and prospective relations between these two orders of phenomena are not of primary economic interest.

However, what the attitude of regulating bodies is will be indicated as occasion arises. Commissions with undoubted power to regulate electrical rates have now been at work in the states of New York and Wisconsin for more than a decade and in numerous other states for shorter periods. Still it can hardly be claimed that there has developed a clear-cut body of commission opinion on this subject. The statement needs qualification with reference to the Wisconsin commission, which has contributed its share;[32] but the creation of such a body of quasi-legal principles and applications as is referred to implies a convergence of judgments and precedents from a variety of sources or states. In fact few commissions have even followed the leadership afforded by Wisconsin. This situation is perhaps partly due to doubt as to the possession of adequate powers, but more fundamentally to the diffidence of commissioners when confronted with a subject so complex, both theoretically and practically, as that of electrical rates.[33]

[32] The writer commented on certain leading opinions of the Wisconsin Commission in a note in the Quarterly Journal of Economics, February, 1913. The Commission accords full recognition to the load factor though unduly inclined to assume that differentials thus devised correspond to separable costs. The law of Wisconsin is unusually specific and adequate in this respect in its grant of powers, as appears in the following extract (National Civic Federation's compilation of public-utility laws, 1913, p. 249): "Commission shall provide for a comprehensive classification of service for each public utility and such classification may take into account the quantity used, the time when used, the purpose for which used, and any other reasonable consideration. Each public utility is required to conform its schedules of rates, tolls and charges to such classification."

[33] The conservatism of the Massachusetts commission is illustrated by the following quotations from its opinion in the case of the Edison Electric Illuminating Company of Boston, Mass. Board of Gas and Elect. Lt. Commissioners, 24th An. Rpt. (1908): "Unless a customer can seriously consider generating his own electricity, the value to him of each kilowatt hour furnished by the company has no necessary relation either to demand, quantity or length of use. . . . . If all the customers of the company were dependent on it for a supply, it is believed that there would be little occasion to discuss or attempt to justify differential rates, and that a uniform meter rate, determined by reasonable operating costs and a fair return on the investment reasonably necessary for the public convenience, would prevail

The various public-service commission laws explicity confer the power to fix at least maximum rates. It is also the unquestionable duty of such commissions to prevent "unjust" discrimination. As to principles of differentiation the laws are naturally silent, though the power to prescribe classifications (one mode of differentiation) is sometimes definitely conferred.

But it would seem to be unnecessary to confer express powers in relation to differentiation. The power to prevent discrimination is the power to fix the limits of differentiation and to determine what sorts of differential rates are permissible. What are "substantially similar circumstances and conditions" from the viewpoint of economics, with regard to the company's affording maximum service to the public at a minimum unit cost, is the gist of the matter. If there is any advantage in differentiating, it is to be presumed that a company will utilize to the full the opportunities left open to it. If the commission has not the power to fix and prescribe every detail of a rate schedule, that situation may sometimes involve administrative inconvenience. But even if commissions deal only with principles, leaving business details to be worked out by the companies concerned, they should be able in the long run to control and determine the modes of differentiation. For example, a commission could prohibit plain wholesale or quantity discounts exceeding a certain range per kilowatt hour as discriminatory, and thus compel the electrical companies to find other and more reasonable methods of reaching the large consumers—whether by load-factor rates or density-factor discounts—that are less open to the suspicion of being mere concessions to bargaining power. The commissions have ample power to deal with this question, but they have not fully exercised it. The power to determine what shall *not* be done is in such cases a sufficient, and perhaps the surest, way to find out what is best to do.

It is unnecessary, and it would be ungracious, to establish by citation of page and line the point that commissions have been diffident in dealing with electrical rates. Opportunities to deal comprehensively with the subject have not been so very numerous.

universally. It may be conceded that, if a uniform rate prevailed, there would be some unprofitable customers" (pp. 43-44). The idea emphasized is an interesting variation (or perversion) of the value-of-service theory. Its application would not promote maximum service to the public.

The commissions, like the courts, seldom go below the surface of economic questions. And differentiation in rates, especially in the less familiar forms it is likely to take in electrical rate-making, is not a simple matter. As regards the bearing of the load factor, moreover, the lack of satisfactory means of recording the variation of the load until very recently has been an obstacle to clarification of facts and policies. The large controlling or guiding powers of public-service commissions have only very recently (except in Wisconsin) been exercised comprehensively in relation to electrical rates.

## CHAPTER II

# TYPES AND ELEMENTS OF ELECTRICAL RATES DESCRIBED

Indescribable variety and complexity.

*The rate schedule.* The distinction between light and power rates. Wholesale, high-tension or primary, and breakdown rates. The various rate elements defined. Difference between energy and demand charges most important.

*The energy or kilowatt-hour charge.* Three initial qualifiers. Graduation according to quantity consumed. The step method of size classification. The block method of variation. The latter differs from ordinary wholesale price making. Former more familiar to the public; needs limiting provisos. The so-called straight-line meter rate.

*The demand charge.* The definition of demand. Not to be merely identified with the consumer's individual maximum. His requirement at the time of the system peak most important. The Hopkinson rate—two charges. The most general type of load-factor rate for large consumers. The Wright type of rate. Common for small consumers, the demand being generally estimated. Difference from Hopkinson rate well illustrated by curves. The Kapp rate. Load-factor rates defined.

*The determination of maxima and of the conformation of the consumer's load curve.* The technical situation as regards demand metering. Estimated "active connected load" as a substitute for the actual maximum. "Convenience" lighting. Room and floor area bases. All these methods applied in conjunction with Wright rates. Considerable arbitrariness. Element of averaging in determining the maximum. In effect a discounting of the individual maximum for diversity. Bearing of overload capacity on the proper interval for which to take the maximum. Meter development in relation to existing practices. A public interest involved in load records for large consumers. Variety of substitutes for maximum metering.

*Flat, breakdown, and off-peak rates.* Brief characterization of each. Definition of the flat rate. Small cost of watt-hour metering makes the flat rate chiefly of historical importance. Revival for high-efficiency lighting and for limited demands. Breakdown and auxiliary service for isolated plants chiefly a matter of insurance. The guaranty feature of some rates. Off-peak rates an important application of load factor principles, though of limited availability.

*Initial or service charges.* Nature and basis of this rate element. Meter and consumer charges. Effect upon the variation of the average rate. Meter charge naturally graduated. The minimum bill method less scientic and not in its nature a reason for lowering the kilowatt hour charge. Legal obstacles.

*Lamp renewals.* Free renewals common. Needed allowance in comparing lighting and power rates. Effect of high-efficiency lamps upon company policy. Differentiation in charges for tungstens. Company control not necessarily best.

*The coal clause and sliding-scale charges.* A result of the War's increasing the cost of coal. Its form and the extent of its use. Applied to large consumers only. Relation to efficiency. The analogous wage clause. Permanence of coal clauses.

*Further points and the uncompleted task of description.* Complexity and variety of electrical rates inadequately set forth in the foregoing sections. The surcharge. The prompt-payment discount disposed of. The output rate. Special contracts. Optional rates elsewhere discussed. Still much experimenting.

To describe existing electrical rates is a necessary incident of the present work. Familiarity with their characteristics and idiosyncrasies cannot be assumed. Any sort of descriptive review must ignore much actual variety and complexity. The complexity, however, will be evident even in such a brief survey of outstanding points as is undertaken here. Occasional critical comment, in the discussion of the "demand" charge especially, is mingled with tho description.

## The Rate Schedule

A rate schedule is constituted by a variety of rates applicable to different sorts and conditions of consumers. Each such rate may in turn be variously compounded, graduated and limited.

The distinction between *lighting* and *power* rates is universal. But the tendency is to make of the former a so-called general rate applicable to all consumers to whom the various other, and presumably lower, rates are not open. The power rate then becomes a concession from the general rate, obtained where the energy is used by motors. So with other rates. The designation "lighting rate" is obviously inappropriate where much electricity is used for the various consumers' appliances, including motors, that may be supplied from the lamp sockets of a small consumer. A distinct power rate usually means the installation of two meters for many consumers. But, even though the power consumption be separately recorded, in the case of a rather large consumer for both light and power (like the landlord of an apartment house with elevators to run and corridors to light) the quantity discounts obtained where the kilowatt hours consumed in the two classes are combined may more than compensate for the concession otherwise obtainable under a purely power rate.

The so-called *wholesale* rate is also distinguished in rate schedules, though the best practice will graduate the general rate into the wholesale rate without any sharp break. The wholesale rate refers to low-tension current supplied in large quantities and will ordinarily not include lamp installation and renewal, this matter

being attended to by the consumer as a separate transaction, whether with the lighting company or directly with the manufacturer of, or dealer in, lamps.

A large electric supply company may find some consumers prepared to take high-tension current in large quantities, themselves transforming it with their own apparatus on their own premises. A *high-tension* rate—or *primary* rate, as more generally named—is naturally lower even than the low-tension wholesale rate, the energy being in this case, so to speak, the crude or incompletely manufactured product.

The *breakdown* rate is something entirely different in nature from any of those above-mentioned, having to do chiefly with the insurance of private plants against entire stoppage of the supply of electric energy in case of accident. Hence it is usually characterized by a heavy demand charge.

There are various other rates of less importance, and somewhat special in their nature, based upon peculiarities in the business of one or another class of consumers. These, however, consist of rather slight modifications and new combinations of the rate elements presently to be mentioned and involve a concession to some particular use of electricity—such as for signs, storage batteries, and refrigeration—or to some occupational class of consumer. It should be added that, where a consumer may be eligible for more than one rate, it is the prevailing, and the only reasonable, practice, to give him the most favorable one open to him.

By *rate elements* are here meant the arithmetical factors by which the actual aggregate amount charged a given consumer is computed. Rate classification is a different matter, though the rate elements are often made to subserve the same purpose. Rates are high or low, or (more generally stated) vary in one direction or another, according to the way in which the rate elements are applied. Sometimes it is convenient to name a class rate by the method of its computation. This should not obscure the fact that the distinctiveness of a rate curve, or of the variation of the charge, is one thing, and the arithmetical methods by which a particular curve is obtained are something quite different.

These various rate elements are: Kilowatt hours supplied; time of consumption; "service," or the mere fact of being a consumer; "demand" in a somewhat special sense, or maximum demand,

referring to kilowatts of generating and distributing capacity needed to meet the largest requirements of the consumer; connected load, as a working substitute for individual demand not actually determined; meter or number of meters used, perhaps with some degree of graduation according to the size of the meter. The ways in which these factors are used and combined vary greatly, and sometimes the elements appear under names not above mentioned.

The most important difference among the rate elements is that between kilowatt-hour, or energy, charges, and demand charges. This difference is closely related to the distinction the economist makes between "variable" and "fixed costs." But the emergence of demand charges as separate elements in electrical rate schedules is due to causes characteristic of electric supply, rather than to the very general distinction between necessary running expenses and expenditures for carrying and maintaining capital.

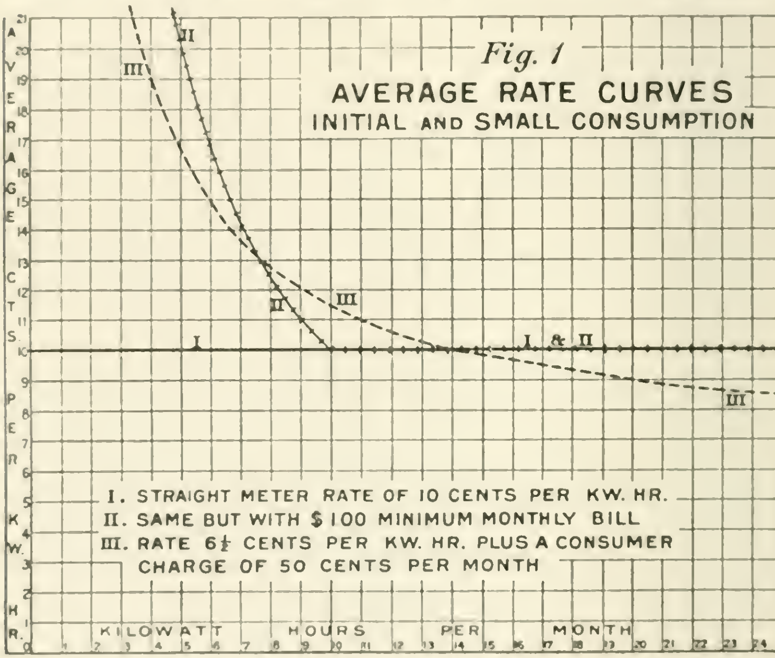
## The Energy or Kilowatt-Hour Charge

The fundamental rate element is the kilowatt hour. Indeed the charge may be computed entirely on the basis of kilowatt hours consumed. If there is an unchanging rate of (say) ten cents per kilowatt hour without qualification, the result is a straight kilowatt-hour rate, or a straight-line meter rate. But the rate may be qualified as regards initial consumption and there may be quantity discounts available for large consumers.

The initial price may be raised by a meter or a consumer (or "service") charge; or by the collection of a minimum amount billed whether the consumer takes energy enough to owe this amount at the usual rate or not. This subject is dealt with in a later section. The effect of both of these qualifiers upon the charge per kilowatt hour for initial and small amounts of electricity is best shown by way of curves. The accompanying Figure 1 explains itself. The variation of cost on account of the small consumer may without hesitation, merely on general grounds, be affirmed to conform more nearly to the type of rate curve when there is a consumer or meter charge than to either of the other two shown in connection with it.

The kilowatt-hour charge seldom remains level at the rate available to the small consumer. It is graduated, presumably for each rate class, according to quantity consumed.

The lowering of the rate where large quantities are taken may be effected by simply classifying consumers by size, that is, according to volume of consumption per year or per month. This means that, for example, a consumer taking 250 kilowatt hours a month




will pay a nine cent rate on all his consumption, where one taking only 10 kilowatt hours will pay ten cents. This is the step principle of graduation.[1]

A much better way to graduate the kilowatt-hour rate is to retain the original rate on a fixed initial block, decrease the rate on the next additional block of a prescribed quantity, compute at a bit less a third additional quantity, and so on, as the size of the

[1] According to the terminology of the Rate Research Committee of the National Electric Light Association, Convention proceedings, 1912, vol. 1, p. 199. An excellent definition from the 1917 N. E. L. A. Rate Book (p. 6) is as follows: "The term 'step' indicates that a certain specified price per unit is charged for the entire consumption, the rate depending on the particular step within which the total consumption falls."

consumer increases. The comparison between these two modes of scaling down the rate as the quantity of energy consumed increases is best shown graphically as in the accompanying Figure 2, where the average rate curve resulting from a "block"[2] scheme is compared with the corresponding blocks and also with steps that would appear to give something like the same general effect.

The nature of the block method is effectively as well as curiously illustrated in the so-called "one-cent sale," by which the

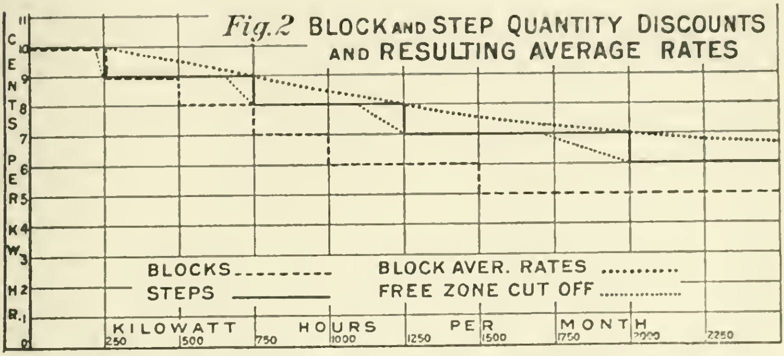


*Fig. 2* BLOCK AND STEP QUANTITY DISCOUNTS AND RESULTING AVERAGE RATES

Hypothetical data of Figures 2 and 3. Rates per month per kilowatt hour.

| *Quantity Block Rate* | | *Step Rate (by consumer size-classes)* | |
|---|---|---|---|
| Up to 250 | 10 cents | Less than 250 | 10 cents |
| 251- 500 | 9 " | From 250 to 750 | 9 " |
| 501- 750 | 8 " | " 750 " 1250 | 8 " |
| 751-1000 | 7 " | " 1250 " 2000 | 7 " |
| 1001-1500 | 6 " | " 2000 " 3000 | 6 " |
| Over 1500 | 5 " | More than 3000 | 5 " |

purchaser may obtain two of an article on sale by paying one cent more than the nominal price of one. In fact, of course, he pays, for example, 13 cents a jar for two jars of jam, and not 25 cents for the first and 1 cent for the second. In the sale of electricity, similarly, the true rate is the average for whatever quantity is taken within the bill period. The fact that the rate varies continuously, instead of by well-defined steps, should not be allowed to confuse the issue.

It is significant that, in graduating the rate to meet the expectations of large consumers, the electrical companies encounter a difficulty that does not occur with ordinary wholesale prices. If,

[2] According to the terminology of the Rate Research Committee of the National Electric Light Association, Convention proceedings, 1912, vol. 1, p. 199.

for example, 7 cents per kilowatt hour is an appropriate rate for a consumer taking 1000 kilowatt hours or more a month, and $4\frac{1}{2}$ cents per kilowatt hour for a consumer taking 10,000 kilowatt hours or more, the ordinary commercial practice would be to state the rate in that way; just as one rate is quoted per dozen, and a rate proportionately less per gross. But in that case there would be consumers taking somewhat less than 10,000 kilowatt hours who would pay somewhat more than those taking just that quantity or a little in excess of it; so that at a certain stage a consumer would have the incentive to use more energy in order to reduce his bill. Although, as will appear presently, this problem can be dealt with by a proviso to the effect that a consumer taking not more than 10,000 kilowatt hours shall pay not more than $450, such a device still leaves a free zone for the consumer just under 10,000 kilowatt hours, where he can use energy without increasing his bill. Hence the more general solution is to frame the schedule on the so-called "block" instead of the "step" principle. By this method the large consumer pays for an initial block at the same rate as the small consumer and for successive further blocks at decreasing rates, so that the average rate varies continuously with the size of the consumer.

The step method of making quantity discounts is perhaps favored somewhat by the preference of the public for a definite and uniform price per unit. This preference may find unintended expression in the rate practices of a manager or he may consciously choose the step method with reference to simplicity and to what the public considers a fair price. A large consumer understands the rate better if he pays six cents for all the energy he purchases than he does where he pays ten cents for a first block, nine cents for a second, and so on. This feeling is due only in part to his reluctance to exercise his arithmetic. It is partly due to the fact that the ordinary wholesale prices with which he is familiar in other fields are of the step type. But, though cost per unit declines as quantity consumed increases, for electricity supply it certainly does not decline after the manner indicated by the step method.

The points where the rate changes from step to step may be safeguarded by limiting provisos, to the effect that the consumer of a quantity equal to or greater than that at the edge of the step shall pay not less than the aggregate amount called for by the rate at that

point. The effect of such provisos on the curve is shown in Figure 2. They remove the incentive the step method offers to consumers in certain situations to waste energy in order to pay less money, but there remain free blocks or zones under such a schedule where the consumer pays nothing for additional energy taken. Such a proviso cuts off what would otherwise be a block or zone supplied at a negative price and makes it merely gratuitous. These free zones or negative-price zones may be made of no importance only by having the steps so small and numerous as greatly to increase the complexity of the schedule. Hence the block type of rate is preferred as the more equitable method of effecting quantity discounts.[3]

The various commissions, as well as the Rate Research Committee of the National Electric Light Association condemn the step type of rate.[4]

The effect of the two methods can be compared to good advantage by means of curves designed to show the variation of aggregate quantity with aggregate price, as well as by means of curves of the demand type familiar to economists and already employed in Figures 1 and 2. Curves of the first mentioned type are presented in Figure 3. Hypothetical quantities the same as those used in the preceding figure are employed. In this case the effect of the

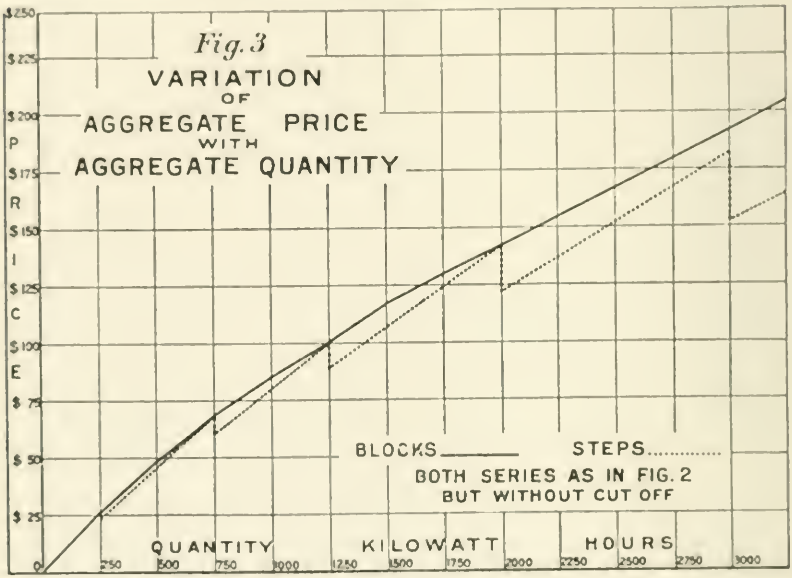
[3] "Increment rate" seems to have been the Wisconsin Commission's term for the quantity-block rate.

[4] The summary statement of the 1916 report of the Committee on Public Utility Rates of the National Association of Railway Commissions is as follows: "Such [step] schedules have been disapproved by various state commissions and they should be superseded by block or other proper form of schedule." Proceedings of the 28th Annual Convention, 1916, p. 103.

The Illinois Commission specifically condemns the step rate as "objectional and discriminatory at the points where the steps occur" (Belleville v. St. Clair County G. & E. Co., (P. U. R., 1916B 24, 60). The same Commission in a latter opinion says: A so-called step rate of itself is inherently discriminatory in character. P. U. R. 1917E 210. Likewise the Oregon Commission, P. U. R. 1918D 683.

The development of the rate schedule of the New York Edison Company in this respect is interesting because of the conspicuousness of that company in the matter of pure quantity discounts. Prior to 1911 free zones and limiting provisos were characteristic of the rates offered. The revised schedule thereafter eliminated them from all except the wholesale rate, where such a free block (in 1912) appears for consumption between 781,250 and 833,333 kilowatt hours per year. The purpose evidently was to put the wholesale rate beyond this point on the straight 3-cents per kilowatt hour basis. Only by some such means can a strictly block rate be brought to a fixed level. (The other possibility is a proviso to the effect that the average rate shall not go below a specified price, say 2 cents per kilowatt hour—which looks invidious.) In the 1915 schedule the block principle is applied in all strictness to the wholesale rate. There is therefore no free zone and nobody gets as low an average rate as that scheduled for the largest block. Any increase in consumption therefore continues to lower the average rate slightly in approach to the rate for the last block as its mathematical limit.

presence or absence of a limiting proviso as to aggregate price is not indicated because it is scarcely appreciable on the scale used. The indicated irregularity of the step method can of course be made negligible by increasing the number of the steps and reducing their width, in respect to both quantity and price. The step curve is noticeably irregular, if the steps are as large as one cent.[8]




[8] The 1917 N. E. L. A. Rate Book (p. 5) divides meter rates into three classes: Straight line, Step and Block. A nominally straight-line rate, however, is not significant if the rate schedule provides for other rates and rate classes such that, for example, only small lighting consumers, of a size that would leave them within the first block of an ordinary block rate, are in fact served under it. Often, too, the rate described as straight-line is subject to quantity discounts which make it, as analytically examined, simply a step rate. The following tabular statement shows what is called a "Straight-line Meter Rate" in the Rate Book, also its translation into step terms.

10 cts. per kw. hr. subject to the following quantity discounts

| | | | | |
|---|---|---|---|---|
| 10% | on bills | $1 | to | $10 |
| 15 | " " | 10 | " | 15 |
| 20 | " " | 15 | " | 30 |
| 25 | " " | 30 | " | 50 |
| 30 | " " | 50 | " | 75 |
| 35 | " " | 75 | " | 100 |
| 40 | " " | 100 | and over | |

Step rate exactly corresponding—rates by consumer size classes as follows

| | | | | | |
|---|---|---|---|---|---|
| 10c. | up to | | 10 | kw. | hrs. |
| 9c. | for | 10 to | 100 | kw. | hrs. |
| 8½ | " | 100 " | 150 | " | " |
| 8 | " | 150 " | 300 | " | " |
| 7½ | " | 300 " | 500 | " | " |
| 7 | " | 500 " | 750 | " | " |
| 6½ | " | 750 " | 1000 | " | " |
| 6 | over | | 1000 | " | " |

Under such circumstances the straight line rate is not fundamentally significant and the term has not even much descriptive value. One fourth or more of the 40 or more retail lighting rates classed as "straight-line" in the 1917 Rate Book are, on the face of the schedules, not in substance such, being subject to quantity discounts (sometimes nominally prompt payment discounts), or alternative to optional rates of a different character, or subdivided by occupational classes, etc.

### The Demand Charge

According to the definition of the Standards Committee of the American Institute of Electrical Engineers "The demand of an installation or system is the load which is drawn from the source of supply at the receiving terminals averaged over a suitable and specified interval of time." Although the word "interval" suggests a short period of time, there is nothing in the nature of the idea to prevent the use of the term "demand" with reference to an average of conditions for the aggregate of days and seasons that make a year. In this way the idea would then connect up with kilowatt-hour consumption and with the ordinary conception of economic demand. But the term "load" connotes a burden put upon the electrical system, which depends upon the time when the energy is taken, and thus upon the conformation of the curve of consumption, or upon its valleys and peaks, more than upon the average of economic demand for, or consumption of, kilowatt hours. If the rate of supply necessitated for a brief interval—whether at some unexpected time, or regularly during each day at dusk, or during each year at the time of the winter solstice—determines the burden upon the electrical company, then the load and therefore the "demand," in the meaning of the word that is critical or essential for electricity supply, is constituted by one or another of these peaks, or by an average for the peak interval. The significance of the averaging suggested has to do with the elasticity and overload capacity of generators, and does not imply that an average of varying conditions is technologically or economically equivalent to actual fluctuations for any considerable length of time.

"Demand" is therefore commonly understood as referring to maximum demand or maximum load. Whether the former or the latter phrase is used depends upon one's viewpoint as relating to the consumption end or to the supply end of the transaction. The maximum demand is the greatest occurring within whatever longer period may be under consideration—a day, a month, or a year. But as the term demand is used, the word "maximum" may often be understood before it. A reference to demand rates and demand charges carries this implication.

However, especially for rate-making purposes, not enough has been said when the demand has been identified with the con-

sumer's maximum. The matter of fundamental importance is the burden put upon the generating equipment and the distribution system. If the maxima of a group of consumers do not coincide, the burden is less. If the maximum of one consumer comes at a time when the central station's load is small, it may be that his maximum is a result of the favorable conformation of his load curve and is the opposite of a burden to the electrical company. Especially if we have in mind the demand charge, it is obvious that the reference should be to the requirement of the consumer at the time of the station peak rather than to his individual maximum. The acceptance of the consumer's maximum as the measure of the burden put upon the generating and distributing system is a pitfall of much electrical rate theory.

A consumer's "demand," when spoken of in relation to a kilowatt or demand charge, is properly thought of as the generating and distributing-plant capacity which his consumption makes it necessary for the company to provide. Taking it for granted that the consumer's individual peak is the best index of his demand implies that the kilowatt capacity required to supply him is equal to or proportionate to his maximum. This assumption ignores diversity. For purposes of rate-making diversity must be taken into account. The consumer's requirement, whether high or low, at the time of the station peak, not merely his maximum regardless of the time when it occurs, must be considered. The individual maximum should be treated chiefly as a point of departure in reckoning the consumer's demand. The conception of a demand charge should not be allowed to be dissociated from the idea of the amount of fixed capital an electric-supply company is required to furnish on account of the individual consumer or class of consumers whose rate is in question. These remarks are a necessary preliminary to the review of actual "demand" charges.

The demand charge may be constituted in various ways. The question as to whether or not it is to be considered of the nature of a demand charge depends upon its purpose and function, not upon whether it explicitly makes use of the consumer's maximum. The charge may be based on the consumer's maximum, upon his connected load or some derivative thereof, or upon his "simultaneous" demand; and it may be collected explicitly as such or by way

of varying the kilowatt-hour rate according to load-factor considerations.

Let us consider first the species of demand charge that is based directly on the consumer's maximum. The combination of this with a kilowatt-hour charge yields the familiar two-charge rate, the consumer paying so much per month or per year for each kilowatt of his maximum demand as a separate charge additional to a correspondingly lower kilowatt-hour charge for energy used. Wholesale rates and power rates are commonly constituted in this way; but seldom ordinary lighting rates. Such a contract may provide, for example, for a charge of $24 per year per kilowatt of maxium demand and in addition 4 cents per kilowatt hour. In honor of its inventor,[6] this is often denominated the Hopkinson[7] rate.

While the writer knows of no instance of a rate schedule where the consumer's "demand" for the purpose of computing a rate under such a schedule has been directly defined otherwise than as his individual maximum—indirect effects of methods of estimation are another matter—without regard to its relation to the system peak, there is nothing in the nature of the Hopkinson plan that would thus restrict it. The "demand" might be defined as the consumer's requirement at the time of the system peak, or any conceivable modification of such a method might be employed in connection with this rate type. So interpreted, the Hopkinson two-charge rate is a thoroughly logical application of economic analysis. That its inventor did not himself more carefully analyze the meaning of demand is attributable to the pioneer character of his conception. He speaks of electricity supply in relation to lighting needs only, as was natural at the time he wrote. The "di-

[6] See his Presidental Address to the Junior Engineering Society, 4th Nov., 1892, on the Cost of Electric Supply (from the Transactions of the Junior Engineering Society, vol. III, part 1, pp. 1-14), in Original Papers, by the late John Hopkinson, vol. 1, Technical (Cambridge University Press, 1901), pp. 254, 268. The paper is also printed in The Electrician (London), vol. 30, p. 29. The greater part is also reprinted in Rate Research, vol. 2, 1912, pp. 23-28. John Hopkinson was a noted technologist and professor of electrical engineering in King's College, London, who died in 1898.

[7] Both the Hopkinson rate and the Wright rate (described below) are not only commonly so called in England and the United States, but it appears are also known by these names in other countries. (Cf. Gustav Siegel, *Die Preisstellung beim Verkaufe Elektrischer Energie*, Berlin, 1906.) The Rate Research Committee approves the usage in question, especially as regards the name Hopkinson, as appears in Rate Research, vol. 2 (1912-13), p. 160, though the terminology there suggested is not very clearly presented. Both designations are regularly employed in the N. E. L. A. Rate Books.

versity factor" it appears, was not broached or defined till electricity supply had grown to something like its present importance.[8] On the other hand, the term "load factor" was used by Hopkinson, in the 1892 paper referred to, in a way to imply that his public was familiar with it.[9]

It should be noted that the demand charge as well as the energy charge under a Hopkinson rate may be of the block form. This is slightly less usual for the former than for the latter element.

The Hopkinson type of rate is the most generally employed rate for large consumers, both light and power. It is recommended for such use by the Rate Research Committee of the National Electric Light Association.[10]

Another method of taking account of "demand"—one not uncommonly applied to small consumers—makes the computation of the aggregate price depend specificially upon kilowatt hours

[8] But Hopkinson (p. 261) shows a clear conception of its conditions and effect.

[9] Hopkinson's paper contains a passage of interest in relation to the history of the term and the beginnings of the Hopkinson type of rate. He says (p. 256): "The term 'load factor' proposed by Mr. Crompton is as constantly in the mouths of those who are interested in the supply of electricity, as volt or ampere or horsepower. The importance of the time during which a supply of electricity is used was so strongly impressed on my mind years ago that in 1883 I had introduced into the Provisional Orders . . . . a special method of charge intended to secure some approach to proportionality of charge to cost of supply." The clause referred to is quoted (p. 261) as providing for "a charge which is calculated partly by the quantity of energy contained in the supply and partly by a yearly or other rental depending upon the maximum strength of the current required to be supplied."

R. E. B. Crompton, it appears, introduced the term "load factor" in a paper on the subject of the cost of electricity read before the (British) Institution of Civil Engineers on April 7, 1891, published in its Proceedings, vol. CVI, p. 2. The term is there described as the ratio of actual output to what the output would be if a plant or engine were worked continuously day and night at full load for the same period; but the ratio to maximum load is what is actually treated. For the economist the ambiguity is not unimportant, even though the best way of defining and determining the magnitude of the maximum may not be clear. The relation of the average to the maximum load is entirely an economic question. The relation between maximum demand and rated capacity, on the other hand—though the two may sometimes be equal and should tend towards equality—is entirely a technological question, so far as it is affected by the efficiency of the different sizes of operating units, and also largely such, so far as having reference to the need of providing reserve capacity for future growth and for possible emergency requirements.

[10] In the following terms (Convention proceedings, 1912, vol. 1, p. 190): "The Committee agrees unanimously in recommending that all large customers be charged on a schedule making separate and distinct demand and energy charges. They recognize, however, that there are local conditions under which quantity discounts, or a straight-line or block rate involving quantity, seem desirable." One may infer from certain remarks in the discussion of this report that the last sentence is largely a concession to the views and practices of the New York Edison Co. The 1916 report (Convention proceedings, 1916, general vol., p. 214) says: "We note the almost universal use by consumers of large size, and the increased use by power consumers of medium and even very small size, of that form of rate which makes separate and distinct demand and energy charges, which use was unanimously recommended in the 1912 report."

consumed, but by way of a kilowatt-hour charge that varies with reference to hours' use of the consumer's maximum. If, for example, the maximum is determined at one kilowatt, then the aggregate price will be computed at the rate of, say, 12 cents for the first 30 kilowatt hours in a given month, plus 6 cents for further consumption from 30 to 60, plus 4 cents for kilowatt hours in excess of 60 taken in the particular month.[11] It should be noted that the gradation is on the block principle. Such a rate is probably more acceptable to the public than the Hopkinson type, because it appears to be merely a modified kilowatt-hour charge and does not require the combination of two charges independently computed. For the maximum demand—which even now it is scarcely practicable to ascertain definitely for each individual—some substitute considered representative of this quantity is usually employed in applying this type of rate. The irregularity of the downward gradations in the illustration above used is typical. It is evident that the scheme is intended to tax the short-hour user and encourage long hours' use, the latter sort of use being considered, on load-factor grounds, less costly to the company.[12]

The introduction of this scheme was due to Mr. Arthur Wright.[13] It is more recent, but the writer believes cruder, than the Hopkinson method. But the scheme has the approval of the Wisconsin

[11] This type of rate may also be expressed by way of percentages of a determinate "monthly maximum consumption," for example, the first 6 per cent at 9 cents, next 6 per cent at 6 cents, all in excess of 12 per cent at 4 cents.

[12] The 1917 N. E. L. A. Rate Book's definition (p. 9) is as follows: "The term 'Wright Demand Rate' applies to that method of charge in which a maximum price per unit is charged for a certain amount of energy and one or more reduced prices per unit are charged for the balance, on the block principle, in accordance with a schedule based upon the use of the maximum demand."

[13] His historically most important paper Cost of Electricity Supply, was printed in The Electrician (London), in 1896, vol. XXXVII, p. 538, and is reprinted in Rate Research, vol. 2, pp. 359, 375. A more elaborate discussion by him, entitled "Some Principles Underlying the Profitable Sale of Electricity," is contained in The Electrician, 1901-2, vol. XLVIII, pp. 347, 378, 430. Mr. Wright is also known as the inventor of a type of maximum demand indicator. His choice of the type of rate to which his name is applied was evidently based on practical grounds, chiefly with reference to the maximum price per unit fixed by law, and he considers it merely alternative to the Hopkinson type, and a way of applying Hopkinson's ideas. While the so-called Wright type as now generally applied tends to disregard diversity, Mr. Wright's own conception of rate-making is not open to this criticism. In the earlier article cited he proposes discounting the demand charge on the basis of the diversity factor of the company's consumers as a group, and returns to the subject in the later one. Moreover, in his application of this type of rate at Brighton, maximum demand indicators were used, instead of the basic demand being estimated.

and other commissions, including New York, Second District,[14] and has long been the most generally employed load-factor rate. Although its fundamental characteristic is the incorporation of a demand charge, it appears to be distinct because the method constitutes a complete rate without requiring the combination of two charges.

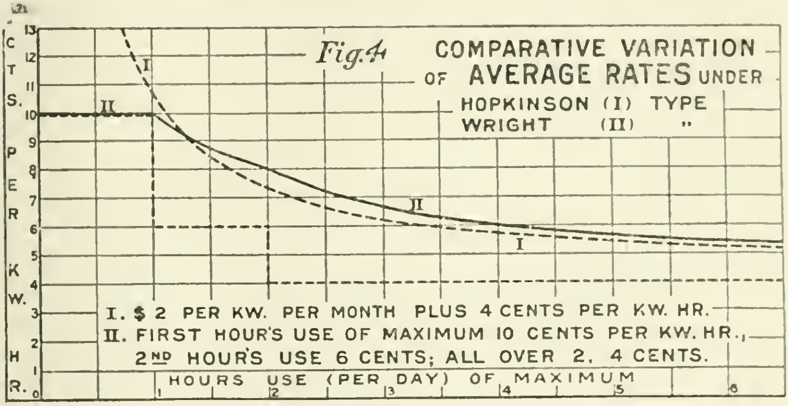
The advantage of this method is apparently due to the fact that the consumer pays so much per kilowatt hour. Kilowatt hours appear to be all he has to pay for. There is no double charge. But let us see, on the other hand, whether the resulting variation of the rate conforms substantially to the variation of cost and whether the plan meets the requirements of a reasonable and just demand charge. In comparison with these matters the advantage of palliating the demand charge is not worthy of consideration.[15]

It is evident that the Hopkinson rate gives a rate curve that varies continuously or by imperceptible gradation in the same way that cost may be supposed to vary. The Wright rate does not yield so smooth a curve even after the initial block is passed. This difference is illustrated in Figure 4. As a result of the level rate for the initial block, it is evident that the consumer with less than one hour's use per day has his demand charge (or what is in effect that) reduced in proportion to his decreased use. This is in glaring contradiction to the whole theory of the demand charge. It may be defended, it is true, as a means of encouraging the small consumer. Its effectiveness in this direction, however, is indirect and partial, for it confuses the small consumer with the short-hour user. Not only are these two far from being the same, but the failure to distinguish them is contrary to load-factor principles. The small consumer is *pro tanto* just as much entitled to benefit on account of a good load-factor as is the large consumer. It is true this criticism applies in theory only to the lower end of the scale where graduation of the rate ceases.

[14] In the Buffalo case, Fuhrmann vs. the Buffalo General Electric Co., decided April 2, 1913. The opinion is not only in itself worthy of examination but also of interest as relating to energy from Niagara Falls instead of from a steam central station.

[15] In a rate schedule the Wright type often appears extremely complicated. This is due to the ingenious devices employed to arrive at a suitable rating of the consumer's premises with reference to what shall constitute the "demand" to which his "hours' use" relates. All the consumer need consider is the extent of the block for which he pays the highest rate. Doubtless the latter's understanding is much less strained by this method than it would by the varying results of an actual measurement of his maximum.

On the other hand, the disappearance of the demand charge whenever there is no consumption within the bill period may be claimed as an advantage of this type of rate. This placates the consumer, but again is indefensible on load-factor principles. It would seem to be wiser in the long run to educate the consumer to the meaning of some kind of demand or service charge. A qualification of this point is necessary, however, with reference to the possible combination of a minimum monthly charge[16] with the Wright scheme. Even then the rate curve remains decidedly irregular. But a rate schedule must deal with averages, not individuals, and simplicity of computation may properly be deemed to




outweigh in importance a considerable degree of irregularity in the curve.

The blanket nature of the Wright type of rate appears in the facts that it may be framed with reference to meeting some of the requirements of a consumer charge and that the basic demand element may easily be modified with regard to diversity. This quality or possibility holds in another respect not yet noted. We shall have occasion later to discuss the density factor as a proper determinant of rates. In this connection it is necessary only to mention the fact that the Wright rate has some relation to the density factor in that it favors an intensive use of the connected load. But this fact is only indirectly and in part correlated with the intensive use of the distribution system, which is the foundation of the impor-

[16] This is a method favored by the Wisconsin Commission.

tance of the density factor in relation to electrical costs and rates. On the room or floor-area basis, the Wright rate becomes more properly a density-factor than a load-factor rate. With a measured maximum the result is different in this respect.[17]

A type of rate that should be mentioned in this connection, though it is historical rather than present practical interest, is one involving the use of an attachment that specially registers any consumption occurring during the station-peak period of (say) two hours, which is charged for at twice the ordinary rate. The device was invented by Mr. Gisbert Kapp, now or recently professor of electrical engineering in Birmingham University (England). It appears to be practically obsolete. The adjustment is not fine, but the method is noteworthy for giving the consumer the full benefit of his diversity. The most important practical difficulty seems to have been in keeping the clock-work accurate so that the double rate is applied at the right time.[18]

All the various types of rates discussed in this section are referred to by the writer as load-factor rates. They are also known as "demand rates." A load-factor rate is one that either contains a demand charge as one of its elements or in some other way explicitly makes the consumer's load factor, or his relation to the company's load factor, a determinant of the price paid for electric service. In addition to the types already mentioned, off-peak rates, and possibly flat rates—both of which are discussed in a later section—belong in this class. Together with breakdown rates, these constitute a miscellaneous group with load-factor characteristics, but of such restricted or special applicability as to leave them only an incidental place in general rate theory.[19]

17 The charge for the first block of a Wright rate is often called the *primary* rate, that for the next the *secondary* rate, with possibly a *tertiary* following. The terms are rather too general to be entirely appropriate to such use and are not free from objection when applied to the block method generally. "Primary" in electrical rate usage refers also to a rate for untransformed energy. And the "secondary" charge is merely a rate element, and in fact never on actual rate, under the block principle.

18 W. E. Burnand, in an article in the Electrical World in 1912 (vol. LIX, p. 261) entitled *Low Rates and the Development of Central Station Service*, suggests the use of a two-rate meter controlled from the station and with the higher rate dials made to operate only at times of extended peak load, perhaps occasioned by a storm, and not merely at some regular hour. The article is well thought out with due regard to diversity, the need of a service charge, and possibilities of liberal use by small consumers.

19 The 1917 N. E. L. A. Rate Book (p. 6) enumerates four kinds of "demand" rates, as follows: Flat, Wright, Hopkinson, and the Doherty or three-charge rate. The last is simply a Hopkinson rate plus a consumer charge and therefore is not a new species of demand rate.

## The Determination of Maxima and of the Conformation of the Consumer's Load Curve

The method of determining the amount of the demand charge, and even the distinct recognition of the load factor as a rate element, is, of course, conditioned by the state of the art of recording the amount, and the variation, of the load imposed by a consumer.[20] Tolerable demand indicators showing the approximate amount, but not the time, of the consumer's maximum have been used more or less for thirty years. But meters showing the variation of the load by making a continuous printed or graphic record of watt hours consumed during successive brief intervals have been perfected only comparatively recently.

As a consequence of this situation, most load-factor rates have been based on estimate and assumption as regards their distinctive element. Even when the consumer's maximum has been determined (though roughly) by an instrument, its relation to the company's peak has still been dealt with by estimation, classification, and averaging, all applied more or less arbitrarily. In the case of large consumers, the "maximum" has often been specified as a part of the contract between company and consumer and has had little traceable relation to actual maxima. But the company has been able to protect itself by inspection of the consumer's premises, by limiting switches, etc. For small consumers, various classification schemes have been used, especially in conjunction with the Wright type of rate. The use of maximum demand indicators has not been general in this country, though the number of such instruments in use appears to be greater than the number of those that present a continuous record of load conditions.

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though for descriptive purposes it may well be desirable to distinguish it from others in this group. The flat rate belongs logically, but not historically, in the group, since load-factor considerations, though important, among others, in occasioning its present use, had nothing to do with its origin.

Among the various devices for introducing the load-factor element into rates, the tabular form and the graphic form (Schenectady, N. Y.) perhaps deserve passing mention in this connection.

[20] Rate practice and measurement technique reciprocally influence each other. In an article in the Electrical World of February 1, 1919, H. W. Richardson speaks of "an increasing tendency to recognize the justice of differential rates, which indicates that a measured demand is as essential to-day as the watt-hour basis of charge was years ago" (page 219). Notes on Demand Meters (the article from which the above extract is quoted) is an excellent summary of the situation.

It is characteristic of the Wright rate as we in America know it, that the consumer's maximum is determined by applying some scheme of co-efficients to his connected load, in lieu of direct determination of the maximum by way of a demand indicator or otherwise.[21] Under such circumstances the method of determining the "active connected load" is as much matter for public regulation as is the fixing of the kilowatt-hour rate itself. The Wisconsin Commission meets this situation by prescribing comprehensively how the active connected load is to be determined by occupational classes and by a scale of percentages varying with the volume of consumption. The application of a demand charge to all sizes of consumers, it appears, must come to this. Demand indicators have not been found satisfactory for such use. A demand charge for the small consumer, therefore, is based on his connected load, not actually on his maximum load, except so far as very recent improvements in metering have already been applied in a way to change the situation.[22]

There is an obvious and familiar objection to this practice in that it tends to cause the consumer to cut down his connected load and dispense with sockets that are only occasionally used. This does the electrical company no particular good, since its distributing system and probably its generating plant cannot therefore be made of appreciably smaller capacity. The consumer inconveniences himself without resulting gain to the company. It is significant that engineers call the lighting connections that are only occasionally and briefly used—which are therefore likely to be dispensed with when the consumer's bill depends partly on the extent of his connected load—"convenience lighting." Such lights affect the consumer's maximum either not at all or only inappreciably. For these reasons connected load is not a good basis for a demand charge. Nor is the situation much improved by applying a varying scale of percentages to get the "active" connected load.

[21] Such estimation, however, is not essential to the Wright type of rate nor in conformity with the ideas of the engineer for whom it is named.

[22] But a mere meter rate does not meet the needs of the situation. The 1917 report of the Committee on Public Utility Rates of the National Association of Railway Commissioners says: "A straight meter rate per kilowatt hour is flagrantly unfair in that it does not give the long hour user his due, i. e., it does not provide for the most important difference in cost of electricity." 1917 Convention Proceedings, p. 450.

load.[23] Some companies will seal sockets and omit them from the count on a consumer's request.

An important and commonly used method of dealing with the situation just mentioned is the basing of the primary charge under a Wright rate, or the demand charge under a Hopkinson rate, upon floor area or number of rooms—both subject to ingenious adjustments—instead of upon kilowatts actually installed. This leaves the consumer free to install as many lights as he wishes. In practice the room basis may be so dealt with as to verge towards the taxable-value method mentioned below.

All these expedients amount to using a consumer's capacity factor in place of his load factor. This is objectionable on general or theoretical grounds. Maximum demand has no definite functional relation to capacity—for consumers no more (presumably much less) than for central stations. Nevertheless such expedients may be practically satisfactory.

It is doubtless partly because of the tendency under this type of rate to restrict the extent of one's connected load that a table for computing connected loads, the Wisconsin Commission's, for example,[24] will show a markedly descending scale of per cents according to the size of the connected load of a consumer of a given occupational class. This, however, is not an altogether satisfactory expedient. It amounts to giving the large consumer a very considerable quantity discount. This may not be objectionable

[23] The rates adopted (or accepted) after an interesting investigation and report by Chicago in 1913 are of the Wright type for small consumers. But they provide for direct determination of the maximum by demand-indicating devices for consumers having a connected load of as much as 1½ kilowatts and for smaller consumers on request. This is an important point of superiority over most Wright schedules.

[24] In the Madison case (4 W. R. C. R. 746-749) the Wisconsin Commission varies the residence lighting maximum on the basis of active connected load quantitatively by fixing it at 60% of total connected load for 500 watts rated capacity or less, and at 33⅓% for any connections in excess of 500 watts, and similarly it varies the power active load as follows:

| | |
|---|---|
| Installations under 10 hp. and one motor used, per cent active, | 90 |
| " " " " 2 or more motors, " " | 80 |
| " from 10 up to 20 hp. irrespective of number motors, per cent active, | 70 |
| " " 20 " 50 " " " " " " " | 60 |
| " " 50 " 100 " " " " " " " | 55 |
| " " over 100 " " " " " " " | 50 |

The last three classes are to be rated 70 per cent for less than a yearly contract basis. There is in this schedule the possibility of a mere quantity discount of one-third in the kilowatt-hour element in the charge.

The essence of this method is its use of an estimated "demand factor" as defined at page 13, above.

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intrinsically, but it certainly is objectionable when it appears under false colors.[25]

One noticeable feature of the methods of determination of demand in use is the large degree to which measurement or test or the connected load basis are used alternatively at the option of the company, and sometimes apparently with reference only to the company's employing the method that yields the highest figure. But enough companies are actually using graphic meters on large consumers to show the practicability of recording impartially all the facts.[26]

An important phase of methods of dealing with demand relates to what we may call the statistical character of the basic maxima. The *annual peak* is not an average of maxima, but the maximum among daily maxima. When it comes to the actual peak day, the peak will in fact be determined in a way to make it, not the greatest instantaneous load, but the highest indicated or recorded average load for an appreciable interval of time, perhaps thirty minutes. The purpose of rate-making will ordinarily be better served by such an average peak than by the indicated instantaneous maximum or the 5-minute or other brief peak. Thus the maximum, even for the Hopkinson rate in its proper form,[27] is really the average rate of consumption during an interval of time.

[25] The Wisconsin Commission's schedules exhibit the weaknesses of the Wright type. Former Commissioner Halford Erickson may be considered to have been its spokesman in the matter of rate theory. His general public utterances on the subject are therefore especially interesting. In an address on Electric Lighting and Power Rates published in the May, 1914, number of the Annals of the American Academy of Political and Social Science, volume LIII, p. 373, he fully recognizes the importance of diversity. The classification of consumers with reference to average diversity is there considered an adequate method of dealing with it. But this method assumes that the consumer himself cannot be induced to take thought about load factors and deserves no better rate if he does. Certainly the attention of large consumers to such matters not only can be expected but is worth cultivating. In a discussion of Rates for Electric Current by Commissioner Erickson, of earlier date (Paper read before the Wisconsin Electrical Association, April 11, 1909), the subject of diversity is not mentioned. However, in a more recent opinion of the Commission signed by him (City of Neenah v. Wisconsin Tr. L. H. & P. Co., P. U. R. 1915A 380) the diversity factor is referred to as "the most important feature of public-utility ratemaking."

[26] The California Commission says that where a consumer has an option to have (and pay for) a demand indicator he should be advised by the company of conditions that may point to his exercising the option. *Re* San Joaquin Lt. & Pr. Corp., P. U. R. 1917E 411. The 2d Dist. N. Y. Commission says that in order to prevent discrimination demand meters should be installed for all consumers with demand rates. *Re* Lockport L. H. & P. Co., P. U. R. 1918C 675, 740.

[27] Hopkinson himself speaks of the demand charge as based upon a *yearly* peak. Cf. the footnote on p. 52, above. Wright's expressions also are clear as to the annual peak being what is really significant. Indeed in The Electrician, vol. 48, p. 379, the second of the

But in the Wright type of rate the principle of averaging is usually given much broader scope, in particular where the maximum is a matter of classification and is assumed, not measured. The "active load" is fixed for a class of consumers while the actual maxima vary greatly from consumer to consumer as well as from month to month. The consumer under such a rate has no motive to keep down his actual peak. Of course, because of diversity, the actual individual peak may be of little significance.

The degree to which the averaging of maxima among consumers classed together may properly be carried, supposing that it will be done, depends mainly upon the importance of the diversity factor. The diversity factor for a group of small consumers, in particular residence lighting consumers, is especially large. Indeed, it is obvious that the greater the number of consumers taken into account and the briefer their peaks, the greater will be their diversity factor. Hence the larger the class or the more diverse its composition, the less the significance of the individual consumer's load factor in the making of the rate, or, if the actual load factor of the individual be made basic, the greater the necessity of discounting it in computing a fair rate. According to this reasoning the small consumer's load factor is relatively less important than the large consumer's, even after the two have been "reduced to a common denominator" by the aggregation of enough small consumers to weigh equally with the large one as regards quantity of energy taken.

Not only in taking account of load-factor conditions by way of class-average rates, but also in the averaging of a number of peaks of the same consumer, there is contained an element of concession to diversity. But, from the viewpoint of proper recognition of the diversity ratio[28] as being equally important with the individual load factor, such practice is crude.

It is generally agreed that the maximum that determines a demand charge should not be the instantaneous maximum but rather the average for some interval of time, and a 30-minute

1901 articles, he refers to the "futility of comparing anything but annual results." Doubtless it is the application of the so-called Wright rate to small consumers that leads to its being put on a monthly basis, since the amount of the bill in such a case must be definitive for the period for which collection is made—though whether collection should not be made less frequently is a pertinent question.

[28] See Chapter V, p. 128 ff., below.

interval has been recommended by representatives of the electrical companies as a regular standard.[29] Demand indicators are usually "time-lagged" so that the effect of a load is cumulative and a maximum that does not continue for some minutes is considerably less than fully registered.[30] The relation of this situation to overload capacities is obvious. If it were satisfactory to accept the individual consumer's maximum demand as the final determinant of a demand charge, the proper width of demand to be applied for the various classes of consumers would be a highly important rate question.[31] Not only overload capacity but the economic and technical availability of the storage battery as a source of direct-current supply for a short time would have to be considered.

It has already been stated that the method of determining demand is as important an object of rate regulation, at least in principle, as is the kilowatt-hour rate itself. But a satisfactory method has not been easy to find, or has only recently been made so by improvements in load-recording meters, hence the situation as regards demand charges and load-factor rates has been confused and confusing—not least confusing to public-service commissioners—and refractory to regulative treatment.

The subject of demand meters pertains to electrical engineering rather than to economics. A non-technical judgment as to their availability will naturally rely chiefly on the fact that meters adequate to the registering of all the facts needed in order to apply load-factor rates are in common use for large consumers. The optional rates of various companies indicate that a great extension of the use of such meters for medium-sized consumers is economically practicable. That they are not more generally or universally used for large consumers may be due to the greater interest of managers

[29] Cf. p. 14, above, latter part of footnote.

[30] An improved type of "logarithmic" heat-storage meter is discussed in a paper on Rates and Rate Making, by Paul M. Lincoln, 1915 A. I. E. E. Proceedings, pages 2175-2211. In the Proceedings for February, 1918, in a paper on The Character of the Thermal Storage Demand Meter (pages 147-168), the same author says that, in contrast with the block interval meter, his type "gives the true heating effect that fixes the size of equipment and therefore cost that should be assessed against the customer." On the other hand, the meter that integrates kilowatt hours for brief intervals of time—which is the generally accepted type—not merely registers the peak, but records the facts as to diversity.

[31] The subject of the "Effect of the Width of Maximum Demand on Rate Making" has been discussed by Louis A. Ferguson in a paper before the Association of Edison Illuminating Companies (1911) which is printed in part in 6 Rate Research 323, 330. He favors the 20 minute interval. Cf. also the quotation from the 1914 Proceedings of the Association of Edison Illg. Cos. in the footnote at p. 14, above.

in exercising more freely all the bargaining power they possess in order to overcome the competition of the isolated plants. If so, it is a specific public interest that load-registering meters be installed for all large consumers. It is also a general public interest that as much knowledge as possible be available as to load-factor conditions experienced in dealing with various classes of consumers.[32]

Aside from the matter of expense—in regard to which the situation may be met by leaving the small consumer out of consideration—the chief problem is apparently how to make the clock's share in the working of the meter entirely reliable. Frequent inspections are expensive. It ought to be possible to solve the problem for a tape-using meter by providing for registering on the tape the receipt of an impulse sent from the central station at a specified time each day. On this basis the record could be adjusted with entire fairness and practically unimpeachable accuracy. The sending of such an impulse over the distribution system would be entirely practicable and would in no way interfere with the ordinary function of the wires.[33]

In addition to those discussed, there are many other ways, all more or less arbitrary, of obtaining a substitute for the consumer's maximum instead of measuring it. The first report (1911) of

[32] The type of meter which in the opinion of the writer has most economic significance is the one classed and described in the report of the Committee on Meters, N. E. L. A., 1914 Convention proceedings, Technical vol. p. 22 f, as an interval maximum-demand instrument of predetermined time interval with record of the time at which maximum occurred—which may be either a printometer or a graphometer. The decisive advantage of such a meter consists in its enabling diversity to be taken into account to any desired extent, while the individual maximum also is shown. Where the readings are integrated for specified periods of time it is possible to obtain the average maximum for any desired time interval. The recording of instantaneous fluctuations, however, so far as desired, is not provided for by the printometer. If diversity were not in question the matter of the duration of the peak might perhaps be dealt with to better advantage otherwise than through an interval meter. The limitation upon overloading to meet a peak demand depends upon the time during which the overload is carried, since the overheating is a cumulative effect.

[33] U. S. Patent No. 1,181,427 (May 2, 1916) was granted for an invention of which the following is a part of the specification: "The object of this invention is to provide for operating electric signals available for street or other fire alarms, ambulance calls, *the synchronizing of clocks* and other purposes, over ordinary electric lighting networks or power mains, or conductors which are also used for supplying electrical energy in the district or for tramways, and in such way as not to interfere with the ordinary operation of the said light or power mains," etc. Circuit-breakers and limiting switches could be operated in the same way from the central station, so that the hours of use for any group of consumers could be adjusted at the will of the management and diversity assured wherever legitimately expected.

the Rate Research Committee of the National Electric Light Association[34] enumerates the possibilities as follows: Measurement of the demand by instruments; frontage of premises; valuation of premises; connected load in kilowatts or sockets; number of rooms; floor area; cubic contents; ground plan area; constant per customer, etc." The Committee's own expressed preference was for floor area, whether used directly or reduced to number of rooms.

The assessed value (or, in the English phrasing, "rateable value") basis is of special interest to the student of economics. No instance of the employment of this method in the United States has come to the attention of the writer, but its use in England appears to be not uncommon, where, however, it is generally optional as well as restricted to a small class of consumers, especially private residences. Some of the other methods also may have been influenced by the ability-to-pay principle of taxation as well as by load-factor considerations.

In some of these developments the original Hopkinson theory has become obscured. The situation is in part explicable, however, as due to the mixing and fusion of other species of differentiation with such as have reference to the company's load curve or to taxing peak consumers. Indeed, the Wright type of rate, in the form in which it usually appears, is, as has already been noted, rather a density-factor than a load-factor rate.[35]

## Flat, Breakdown, and Off-Peak Rates

There remain two other theoretically interesting modes of rate-making which have reference to the load factor. One, the flat rate, may be described as charging only for demand and not for energy; the other, the off-peak rate, allows no energy to be taken at the company's critical peak time and accordingly makes the kilowatt-hour rate low for times when consumption is allowed. The breakdown rate is related to the first and in effect is (or should

[34] Convention proceedings, 1911, vol. 1, p. 318.

[35] The 1916 Report of the Differential Rates Committee of the National Commercial Gas Association refers to this result as "a new type of rate which attempts to simplify the estimate of demand, by basing the differentiation in the rate upon other considerations, *which reflect rather than measure demand* [italics, the present writer's], such as the number of receptacles, the number of rooms in the house, or the area of floor space actively occupied, and we have a rate which has all the appearances of a demand rate, but is in reality a series of meter or quantity rates with discounts based upon quantity." Pages 29-30 of Appendix I, The Development of Electrical Rates.

be) principally an insurance premium for facilities sufficient to supply a given demand without much reference to whether electricity is actually required or not.

A *flat* rate may be defined as one in which the charge for a given consumer's installation varies only in proportion to elapsed time.[36] For some classes of business a company may prefer to make a rate of so much per year per unit of connected load, thus being enabled to dispense with the metering of energy used. This practice is not indefensible in the case of a hydro-electric plant, but is otherwise nearly obsolete.[37] It amounts to covering all costs by the demand (or, strictly, connected-load or connected-apparatus) charge. But of course the peak is not necessarily the only consideration taken into account in fixing the charge, any more than energy consumption is alone considered in fixing a purely kilowatt-hour rate. Hence the flat rate is not solely a demand charge standing by itself, but it is that essentially.[38] Indeed the flat rate is older than the load-factor concept. But its use in the early stages of the development of electricity supply was due to the absence of inexpensive and reliable devices for the measurement of electric energy. Street lighting is still mainly supplied at a price per lamp per year, as it was in the beginning, but the hours of lighting are a part of the contract. Sign or display lighting is frequently furnished under a flat rate with similar stipulations.

At present kilowatt hours consumed can be determined accurately and inexpensively. This being so, wherever the energy as such is an important element, even if a minor one, in cost, it would seem that, if the quantity taken is optional, it certainly ought to be metered in order to prevent waste.[39]

[36] A *straight-line meter* rate is sometimes incorrectly called flat.

[37] The flat rate is the prevailing type of water rate. The various bases adopted are strikingly like those enumerated above as substitutes for a measured maximum in electrical rate making.

[38] The Massachusetts Board has approved flat rates for the summer business of the Vineyard Lighting Co., where the brief seasonal demand in summer is responsible for almost all costs. 9 Rate Research 200.

[39] The following (from the N. E. L. A. 1915 Convention proceedings, Commercial volume p. 347, remarks of Mr. Harmon) reflects the experience and judgment of one manager: "We found there was no device that we could put on, with the exception of an interrupter, that would prevent people from putting on heaters in the winter when our load was heaviest. We had in all about 5 years experience with flat rates and are now putting in meters."

The reasons why the flat rate is more appropriate for a hydro-electric plant than for a steam central station are almost obvious. Fuel consumed varies substantially per kilowatt hour and the fixed investment is in proportion less for the steam plant. But flat rates may increase the troubles of the water-power plant during periods of low water or inadequate stream flow.

The increasing dominance of the tungsten lamp and high-efficiency lighting, even in very small units, tends to reduce the relative importance of kilowatt-hour cost in the total—the situation in this respect resembling the case of hydro-electric supply—hence there is a tendency to favor a greater emphasis upon the demand charge in some form or other. The lamp situation has, in fact, revived the interest in flat rates, at least as applied to the small consumer.[40]

It appears to be entirely practicable to limit the maximum of such consumers through the circuit being broken automatically upon excess-demand. From the mechanical device adopted to accomplish this, the name "limiter rate" has recently come into use.[41] However, it is not practicable by such means to limit or restrict the time of day when energy is used. On the other hand, such procedure is entirely feasible for certain classes of large consumers—in fact, the current may be switched on and off by the company. Sign lighting, which is frequently the subject of a special rate, may be so dealt with.

An isolated or private electric plant will occasionally need central-station service (1) in case of interruption for any reason, (2) in order to supplement its own generators at times of special demand, or (3) for auxiliary service at intervals of light load. In the second case the central station is called on for aid in tak-

[40] The second report of the Rate Research Committee qualifiedly recommends a flat rate for consumers whose maximum will fall between 100 and 300 watts (N. E. L. A. Convention proceedings, 1912 vol. 1, pp. 195, 197). With reference to the problem presented by high-efficiency lamps this maintains simplicity by going from one extreme to the other, that is, from a pure kilowatt hour rate to a pure demand rate. The 1916 report (Convention proceedings, genl. vol., p. 222) recommends a controlled flat rate as an option only. In the 1920 N. E. L. A. Rate Book (p. 12) the situation is described as follows: "Several years ago it was believed that the Flat Demand Rate should not be used, but recently this type of rate has again come into use for small residence customers."

[41] The Illinois Commission has sanctioned such rates, at first experimentally (*in re* Central Illinois Pub. Serv. Co., P. U. R. 1916B 14; also 8 Rate Research 165) and later as an established practice (10 Rate Research 102), service being rendered through a 100-watt limiter for $1.00 a month.

ing care of a brief peak that probably comes at about the time of its own peak. But the auxiliary service may be during the night, at times when there is not enough demand to warrant the presence of an engineer at the isolated plant. In relation to possible interruption of service the function of the central station is that of insurance. Under this conception, payment may be justly exacted without the central station being called on at all. The kilowatt-hour charge for the supplementary service can not properly be expected to be low, while for auxiliary service it can be. But an electrical company is specially disqualified for fixing rates for breakdown service—it may even be disposed to refuse the service altogether—because the isolated plants are competitors. The case is one where a demand charge is appropriate. This fact is generally recognized in the making of breakdown rates. Since no load curve is in question, the limiting switch is sufficient to keep the customer within the demand he pays for.

The guaranty feature of some wholesale rates is worth mentioning in this connection. In effect it insures the company a certain income from a particular consumer. This should be superfluous for the company, and if it affects the consumer at all, the effect upon him is undesirable, since it may cause him to waste energy when it appears his consumption will not otherwise approach closely to the amount corresponding to his guaranteed minimum. With reference to wholesale rates it is an application of the minimum-bill principle where there is no excuse for it on account of initial costs to the company, and where, if it means anything, that must be because the rate is not properly graduated between wholesale and retail consumers. It is worth something to a competitive manufacturing enterprise to be able to book orders for months and years ahead. The monopoly position of a public-service enterprise gives it this advantage unsought. Only in the case of a consumer who takes enough energy in proportion to the total supplied by the company to make it proper to attribute an appreciable part of the plant specifically and directly to his service, instead of his demand being lost in the general mass, is the guaranty feature justifiable. The withdrawal of the ordinary individual consumer cannot as such affect the calculations of the management. His action is significant only in a representative sense and is a matter of merely statistical consideration.

Special off-peak rates under which current cannot be taken during certain specified hours, accompanied by devices preventing such consumption, are an occasional feature of rate schedules. This is not only a thoroughly load-factor type of rate, but it fully recognizes diversity as being quite as important as long hours' use, since the rate is planned with reference to the company's, not the consumer's peak. Once provision is made for protecting the company against use at peak hours—and it is entirely practicable to prevent a large consumer from taking energy during any specified period—this kind of rate offers no difficulties as regards the determination of load-factor and diversity characteristics of consumers. But of course it is of very limited applicability.[42]

A method of dealing with rates generally that is based on a closely related idea, by which a higher rate is charged for certain specified peak hours than for other times, either through a device to make the meter register faster at peak hours or through separate registration, has already been mentioned.[43]

## Initial or Service Charges

The initial or service charge is related to the demand charge, and may to a degree have the same purpose and effect. The latter is sometimes described as a charge for readiness to serve, but it depends upon the character of the consumer's requirements rather than upon the mere fact of his being a consumer. The purposes of analysis and description require the recognition of the distinctively initial charge. This and the demand charge are both proportioned to time, not to consumption. The demand charge, however, varies with kilowatts of maximum or connected load or something similar. The initial or service charge is not necessarily graduated. It is founded upon the cost and advantage of being connected with the system, connection here referring to operating

[42] The 1920 N. E. L. A. Rate Book shows rates for 309 companies, of which number a count shows about 33 with off peak rates or off peak discounts. The distinction is mainly a matter of a smaller or discounted demand charge in consideration of no power or less power being taken at specified peak hours for certain winter months. In a few cases the rate is a low straight meter charge. In some cases the provision is elastic and appears to suggest adaptation of hours of consumption. In the N. E. L. A. 1915 Convention proceedings, Commercial volume, p. 351, Mr. Freeman speaks of a contract entered into with an employer as a result of the latter's having rearranged working hours for his plant so as to end them at 4.30 P. M. Such practice is probably not uncommon.

[43] See page 50, above.

expenses involved in keeping in touch with the consumer and ascertaining how much he consumes, as well as to the cost of providing street-connection, wiring, etc. Only an out-of-the-way consumer supplied under special conditions, however, is likely to be charged according to the expense or the length of the physical "service" connecting his premises with the distribution system.[44]

There are two standard modes of introducing this element into a rate, one the consumer charge and the other the meter charge. The minimum monthly-bill proviso is another rather half-caste method of accomplishing something like the same thing. These have been mentioned above as modifiers of the kilowatt-hour charge. They are still to be considered on their own account.

The consumer charge is a fixed amount per month to be added to the kilowatt-hour charge for the same period. It is designed to provide for certain expenses incident to the service of the consumer which are independent of the amount of energy he takes. They comprise the expense of reading meters and billing and collecting amounts due, including energy losses in the meter,[45] also carrying charges for the separable investment made on behalf of the individual consumer. This charge, like all rate elements, is based upon cost-analysis, but is distinguished from the demand charge as having reference to operating expenses more than to fixed charges. The most important practical objection to it is that it tends to scare away small consumers and thus restrict the business of the electrical company.

With a consumer charge it is evident that the average rate per kilowatt hour used becomes very high where, as may happen dur-

[44] Usage is not definite and settled as regards the meaning of the term "service charge," hence the alternative "initial charge," as used above. An early definition by Mr. Arthur Wright (1901 article, p. 348) is contained in the following: "The cost of maintaining the necessary service lines, meters and attending to consumers' accounts, complaints, and collecting the revenue. These *Service Costs* are roughly proportional to the number of consumers."

The "readiness-to-serve" charge is clearly a demand charge. Doubtless because of the resemblance between the two terms and because of the need of shortening "readiness to serve," demand charges in general are commonly called "service" charges. Of course the service charge properly so called does not relate to the *amount* of service. It is equally true that the kilowatt-hour charge does not relate directly to the amount of service (i. e., of actual or potential benefit furnished). For lighting uses, however, there is available a true service unit—or as near to one as physical measurement can come—in the candle hour. For power uses, on the other hand, the available units relate almost entirely to mere performance.

[45] The energy lost in the meter coils is not unimportant relatively to the amount consumed by a small consumer. On the other hand the consumer pays for losses in his own installation.

ing vacation time, almost no electricity is used. The consumer, it is true, pays at the high rate for an inappreciable amount of energy (or in fact for something else), and his bill is consequently very small. But people object to paying other than a constant unit price, and especially to paying something when they get nothing, and they are not willing to admit that mere "readiness to serve" is a service, or that reading (or attempting to read) the meter and collecting the bill are services *to the consumer.* From the point of view of the company, therefore, even apart from public prejudice or legal necessity, it is well not to be too exacting in the matter of a consumer charge. For the later reaches of an average rate curve that shows the variation of average cost and price with quantity consumed, that is, for large consumers, the initial consumer charge has no appreciable effect.

The meter charge has practically the same basis and effect as the consumer charge, except that it provides for some degree of graduation according to the number of meters a consumer may have and also according to the size of the meter. Since the meter capacity is to some extent an index of the "active" connected load of the consumer, this feature assimilates the meter charge to the regular demand charge. But it is not to be expected that the graduation by size will take account equally of kilowatts of capacity regardless of their position in the scale; that is to say, a 10,000-watt meter will not carry a charge 20 times that for a 500-watt meter, but more likely one in proportion to the comparative cost of the two meters. Another important difference to be noted is the fact that the administration of the meter charge is a simple matter and it is applicable with ease to small consumers, while the straight and strict demand charge is administratively impracticable except for large consumers. The fact that the meter charge is based largely on operating costs has already been mentioned.[46]

A minimum charge of (say) $1 per month serves the purpose of a consumer charge, though without precision, and it allows the consumer without further charge to take a return in kilowatt

[46] A well known early advocate of complex rates, Mr. Henry L. Doherty, in a paper entitled Equitable, Uniform and Competitive Rates, read before the National Electric Light Association in 1900 (Convention proceedings, 1900, p. 289), proposed both a meter and a consumer charge in addition to demand and energy charges, making four elements. In later writings he combines the former two, the result being what is often called the three-charge rate.

hours, if he will, thus humoring his prejudices.[47] It is thus like the guaranty feature above mentioned (page 67).[48]

The adjustment is not nearly as scientific as under either the consumer or the meter charge, as may be observed on inspection of the comparative curves of Figure 1. Correct adjustment, however, is largely a question of averages, as has been remarked. But this method has one important disadvantage from the viewpoint of the public as compared with the others, that is, the adoption of the minimum-bill proviso affords no ground for a lowering of the initial kilowatt-hour rate. The meter charge, on the other hand, (and likewise the consumer charge) is definitely enough an additional charge reasonably to carry with it such a reduction. A reduction at this point encourages more liberal consumption by the small consumer, which is just what the company needs. Economy of kilowatt hours on the part of small consumers means no corresponding saving to the company and a rate system that specially encourages it is an obstacle to the profitable free utilization of electricity by the public.

Legal obstacles to the use of any form of initial charge frequently prevent a scientific adjustment of the rates at this point. The form of the Wright type of demand rate has been affected by this situation. The legally or contractually established maximum rate per kilowatt hour is similarly effective against the minimum charge, the consumer charge, and the meter charge. Sometimes

[47] In the Ashtabula Gas case the Ohio Commission says: "A minimum charge implies that it will be absorbed in the rate in case a certain amount of gas is used." 11 Rate Research 261. The Massachusetts Board marks a sharp contrast between the meter charge and the minimum charge, as in the following from its 25th Annual Report (1909), page 38: "It may be conceded that strong arguments exist for a meter rent or service charge, but they are not the arguments which support the imposition of a minimum monthly charge. Whenever a meter rent or service charge is imposed, it appears to be as much for the express purpose of raising a definite revenue as the price per kilowatt hour for electricity consumed. On the other hand, the facts show that, as a revenue producer, the minimum monthly charge is almost a negligible factor, and this leads to the conclusion that its value is negative rather than positive." A Massachusetts legislative enactment of 1913 in effect authorizes a minimum charge of not more than $9.00 a year by providing that there shall be no meter rent if the consumer uses electricity in a year to the value of $9.00. 14 Rate Research, 24-25.

[48] The special emphasis of the New Jersey Public Service Commission on the guaranty function of the minimum charge as of primary importance appears (*in re* Newton Gas & Electric Co. P. U. R. 1916A 532) in its "approval of a scheme of minimum charges, not, however, based on the cost as reflected by the varying demand of different customers, but so designed as to prevent the curiosity seeker from inflicting a burden upon the company, and sufficient in amount to compensate the company for the costs of maintaining and reading meters, bookkeeping, collecting and the general costs which are more or less proportionate to the number of customers."

there is a specific provision against any meter rental, which, since it is directed at the form rather than the substance of the charge, is easily avoided, unless the language of the law is very comprehensive. A legal or contractual maximum per kilowatt hour directly destroys or mutilates a minimum charge.

If the fixed maximum rate is high, however, initial charges may be adopted which are effective only to raise the general rate to the maximum for small consumers and are entirely ineffective at no consumption. For example, if the maximum is 15 cents and the general rate available to small consumers is 8 cents per kilowatt hour, a minimum charge of $1.00 a month is effective in raising the rate from 8 cents for 13 kilowatt hours a month ($1.04) to 15 cents for 6 2/3 kilowatt hours ($1.00) or less, 4 kilowatt hours being chargeable at not more than 60 cents, etc. It should be noted that under this arrangement there is a free zone between 6 2/3 and 12 1/3 kilowatt hours a month. The illustration supposes that the minimum charge is on a strict monthly, not annual, basis, or, in other words, that the portion of the $1.00 collected in excess of enough to cover the consumption at 8 cents is not applicable for kilowatt hours consumed in another month that are above the reach of the minimum charge as applied to that month separately. The latter sort of charge, though collected monthly, may actually be a per year minimum of $12.00. This point is dealt with in the next chapter in discussing the grounds for preferring the meter charge.

Contractual maxima based upon agreement with a municipality have been interpreted as referring only to the output charge, thus not preventing the establishment of another charge serving a different purpose alongside of and supplementary to the former.[49] Such an interpretation of the law when it has been applied to statutory maxima and franchise grants, as distinguished for ordinary contracts, has been defeated in the courts.[50] However, such a charge may be put into effect as part of an optional rate which

[49] Thus the Ohio Commission, in the Lima Natural Gas Company case, June 2, 1919, says: "We do not agree that a readiness-to-serve charge is a charge for gas." 15 Rate Research 342.

[50] The New York Court of Appeals in dealing with certain decisions of the 2nd. District Public Service Commission.

the consumer may choose in place of being served at the legal maximum.[61] Such a method will probably leave a considerable number of small consumers served at a straight kilowatt-hour rate.

### Lamp Renewals

The supply and renewal of lamps for a lighting consumer is still in many cases covered by the regular charge per kilowatt hour.[62] Even in these cases, however, for large consumers the rate is made without lamps, leaving the consumer to purchase them independently. Other than standard lamps are, of course, purchased, but usually, if purchased from the electrical company, at a special discount to customers that are entitled to free renewals, since such lamps take the place of standard lamps that would otherwise have to be supplied.

In comparing lighting and power rates allowance must be made for the fact that lamps are not needed in the latter case. Inspection of a company's schedule will usually reveal what it believes (or prior to war increases in cost believed) to be the equivalent of the lamp.[63]

The development of high-efficiency tungsten lamps of small sizes which cost somewhat more than the standard carbon so that their original supply and free renewal cannot be treated as matters of course gave rise to an interesting situation. Their general adoption, without an increased use of much higher illuminating powers, portended a very much reduced revenue from small lighting consumers, who were already alleged to be unprofitable. Hence

[61] Substantial effect of the method of the New York Public Service Commission for the 1st District in the case of the New York & Queens Electrical Light and Power Company, 1917 N. Y. 1st Dist. P. S. C. R., 87.

[62] According to the 1917 report of the N. E. L. A. Committee on Lamps, 61 per cent of companies reporting to it handled lamps only as merchandise.

[63] The 1911 schedule of the New York Edison Company allowed to consumers under the general rate (which included lamps)) who took above 1500 kilowatt hours a month one-half a cent per kilowatt hour if they wished to supply their own lamps. Many large consumers did not avail themselves of this option. Since May 1, 1915, the kilowatt-hour charge does not include lamps, for which a separate contract at the rate of one-half cent per kilowatt hour is offered. This commutation basis seems to be the one usually adopted in all parts of the United States. Such lamp service was discontinued by the New York Edison Company on July 1, 1918.

they were often supplied to consumers at rates that encouraged the use of the larger, instead of the most suitable, candle powers.[54]

It is quite evident that a company that supplies a 60-watt lamp free and asks prices for the smaller sizes that increase as the size diminishes is not selling lamps to its consumers on ordinary merchandizing principles. It has in view its revenues per kilowatt hour rather than direct compensation for the cost of the lamps. That the consumer should be offered such ostensibly large inducements to use lamps of high illuminating power is not the best way of adjusting the business to the new conditions. On the other hand, it is not easy to determine in just what respect the company should proceed differently. A 56-candle-power unit may be most suitable where very bright illumination is wanted, but it does not appear that the discouragement of the use of small tungstens where a bright light is not wanted is justifiable on general economic grounds, that is, on the basis of a difference in fixed cost for a given period of service as between the tungsten and the carbon-filament lamp.[55]

The expressed desire of prominent central-station men to *control the situation* as regards the supply and renewal of lamps is doubtless in part due to a justifiable wish to prevent the use of technically unsatisfactory connected appliances. But they would

[54] The price list of the New York Edison Company for plain (not frosted) Mazda (tungsten) lamps as of January 1, 1917, was as follows:

| Lamp Wattage | Additional Charge under Lamp Service Agreement | New-sales Price |
|---|---|---|
| 10 | .17 | .22 |
| 15 | .15 | .22 |
| 20 | .12 | .22 |
| 25 | .10 | .22 |
| 40 | .05 | .22 |
| 50 | Free | .22 |
| 60 | Free | .29 |
| 100 | Free | .52 |
| 150 | Free | .87 |
| 250 | Free | 1.42 |
| 400 | Free | 2.54 |
| 500 | Free | 2.76 |

The Commonwealth Edison Co. (Chicago) rents (or lately rented) tungsten lamps at so much a month instead of selling them, in a way to exert a similar influence upon the use of low-wattage high efficiency lighting units. But many companies are now supplying tungstens of 40-watts as regular renewals.

[55] In fact the tungsten now has a longer life in service, under ordinary conditions, than the old carbon filament lamp.

also be not unnaturally disposed sometimes to use such control to discourage the use of the most economical energy-consuming devices. Rate schedules should not be permitted to reflect such a policy. Where lamp service is included under the lighting rate the tendency appears to be towards a sort of compromise by which consumers will obtain 40-watt tungstens free but not the 25-watt lamps that correspond more nearly, as regards candle power, with the old 50-watt gem lamp. The substantial displacement of other types by tungstens has already, in 1919, become an accomplished fact.[56] The next possible development and problem relates to how far the gas-filled lamp will come into domestic use.[57]

It is possible that the recent emphasis upon the benefits of diffused and indirect lighting—the newer ideas of "illuminating engineering"—may be in part due to the not entirely disinterested influence of the electrical companies. Instead of such makeshifts and subterfuges, what the situation calls for would seem to be an explicit recognition of other than kilowatt-hour costs in the rate schedule.

National efforts to further fuel economy during the World War gave the *coup de grace* to the carbon-filament lamp, so far as its

[56] The following comparison—which is condensed from a table in the 1915 Report of the Lamp Committee of the National Electric Light Association, Convention proceedings, Commercial volume, p. 249, with 1918 figures added from page 237 of the General volume for 1919 and 1919 figures from the volume for 1920, p. 41—shows the approximate distribution of domestic incandescent lamps sold (exclusive of miniature) as affected by developments during 12 years. The figures are for sales by the manufacturers.

PER CENT DISTRIBUTION OF TOTAL SALES

| Type | 1907 | 1914 | 1918 | 1919 |
|---|---|---|---|---|
| Carbon | 93.27 | 7.11 | 11.0 | 7 |
| Gem | 5.88 | 22.36 | | |
| Tantalum | .75 | ..... | .... | ... |
| Mazda | .10 | 70.53 | 89.0 | 93 |
| Total | 100.00 | 100.00 | 100.0 | 100 |

Corresponding figures are given for intervening years. Changes for carbon and Mazda lamps are uninterruptedly in the direction shown, the latter first exceeding 50 per cent in 1913. Tantalum lamps rose to a maximum of 3.57 per cent in 1910; and gem to one of 33.59 in 1912. The 1916 committee expected the introduction of the 50-watt Mazda to increase greatly the sales of this type. The production of gem lamps was discontinued entirely early in 1919 (p. 237 of 1919 report) and the committee expected the decline in the use of the carbon lamp to be more rapid than before, in view of the possible development of a specially sturdy type of tungsten lamp.

[57] Of the total tungsten lamps sold in 1918, 142,000,000 were of the vacuum type and the remaining 24,000,000 gas-filled. The former increased 8.5 per cent in number over 1917 and the latter 37 per cent (page 237 of the 1919 report). In 1919, 16.8 per cent of all tungstens sold were of the gas-filled type (page 43 of the 1920 Convention volume).

manufacture and use for ordinary lighting purposes are concerned. Manufacturers agreed not to make such lamps and distributing electrical companies not to supply them, except under special conditions. Hence the tungsten is now standard throughout the country.

As a result of the War there was also a tendency toward discontinuing free lamp renewals of any sort, partly as a means of economy and a war-emergency measure.

### The Coal Clause and Sliding-Scale Charges

Indications that the World War has left its marks upon electrical rate practices have already been noted. The most conspicuous instance of such effects, and an intrinsically interesting contribution to rate making methods, is the "coal clause." It is sometimes a "fuel" clause, where oil is used.

The rapid increase in the price of coal during the winter of 1916-1917 lead to amendments of high-tension and large power rates on the part of various companies looking to a sliding scale for the kilowatt-hour charge depending on the price of coal. The policy was considered important enough to be a subject of discussion in the 1917 Report of the N. E. L. A. Rate-Research Committee. In cases noted (among the earliest) several companies advanced the rate the equivalent of 0.35 of a mill per kilowatt hour for each \$1.00 advance in the price of coal above \$3.00 [58]: another adds 1 mill for each \$1.00 above \$2.25 [59] another, 1 mill for each \$1.00 above \$1.00.[60] We are not here concerned with reasons for the differences in the base, due to local and other conditions.

Before the beginning of 1919, as shown by the 1919 issue of the N. E. L. A. Rate Book, at least 55 companies in various cities had such coal clauses.[61] According to these, for each increase of a given amount (or sometimes a given per cent) in the price per ton over a specified price, the rate per kilowatt hour is increased

[58] New York Edison rider to adjust high tension rate, April 1, 1917; also Brooklyn Edison rider effective June 30; and New York & Queens, similarly, except that the increase is 0.375 mills.

[59] Cleveland Electric Illuminating Company, high tension A. C., 11 Rate Research 51.

[60] Fall River Electric Light Company, Power rate, Electrical World, May 5, 1917, page 857.

[61] A count of the 1920 Rate Book shows this number substantially unchanged.

similiarly by a specified fraction of a cent per kilowatt hour. The increase per ton that is operative to increase the rate is usually 10 cents or 25 cents, but it varies from 1 cent to $1.00, the per kilowatt hour increase in the rate of course varying similarly. The ratio between the two of course is different according to the locality and the cost of coal. The method of computing the average cost, including the period to be taken, is usually carefully specified. Sometimes it is provided that the actual additional coal cost per kilowatt hour shall be computed from the accounts of the company and shall constitute the rate increment. Most of the coal clauses provide for a decrease in the rate for decreased coal cost on the same principle as for an increase. In some cases the starting point, that is, the basic coal cost per ton, is not the same, leaving a neutral zone for the application of the old fixed rate. The basic cost may be for so many heat units (per 1,000,000 B. t. u., for example).

Coal clauses are not applied throughout the rate schedule. They are applied to rates for primary power, less often to large power rates, and sometimes also to general power or small power rates. In one case only railway power is affected. Occasionally the application is to all consumers taking above a certain number of kilowatt hours per month. A general lighting or a general light and power rate is rarely affected.[62]

[62] The New Jersey Board rejected a clause adding one per cent to *all* consumers' bills for each 10 cents advance in the cost of coal, on the ground that the increase was not proportional to fuel cost. 11 Rate Research 361-2; P. U. R. 1917F 205. The same Board shortly after accepted a ⅜ mill per kw. hr. clause for municipal lighting. P. U. R. 1918B 589.

The general use of the coal clause is hardly defensible. Fortunately it is also practically unknown. The Rockford Electrical Company, in its application to the Illinois Public Utilities Commission, stated its reasons for making the clause effective for power rates only substantially as follows: 1. Cost of coal is a much more important factor in power service, hence the operating margin is more affected; 2. Power consumers resorting to other sources still pay the increased cost of coal, while lighting consumers have other available resorts; 3. Power consumers have enjoyed the lowest rates per kilowatt hour, hence should first feel an increase of operating expenses. 12 Rate Research 10. But the Illinois Commission disapproved the proposal (P. U. R. 1917F 196) on general grounds, as involving varying rates from month to month instead of their being "known at the time the service is rendered" and implying a delegation of the Commission's power to fix rates. The Missouri Commission has disapproved coal clauses on similar grounds (P. U. R. 1919A 593). Likewise, the Michigan Commission (Electrical World, Feb. 12, 1921, page 391). For the position of the Pennsylvania Commission, see page 79, below.

The 2nd. Dist. N. Y. Public Service Commission in a decision relating to the Rochester Gas & Elect. Co. (a gas case, P. U. R. 1921A 415) says: "Underlying the rate provisions of the Public Service Commissions law is the principle not only that rates shall be reasonable but that they shall be published and to such a degree stable that the consumer may know

The 1917 report of the N. E. L. A. Rate Research Committee recommended that, if available, the price data of a local coal exchange be used in place of average costs per ton.[63] But it implied that such a basis will seldom be available. The policy recommended would tend to put the burden of bad purchasing policies upon the company and, on the other hand, give it the benefit of special skill in this direction. It is sound. There would doubtless also be a considerable advantage as regards ease and objectivity of the methods used in deriving the increase per kilowatt hour. The Rate Research Committee also says that, if the rate is above a certain minimum, the coal clause should, as a matter of course, provide for a scale of reductions corresponding to the increases. During the period within which the coal clause has been developed, however, such a provision has not been of practical interest, hence its absence need not be attributed to unfairness on the part of the companies.

The idea underlying the coal clause is that of a sliding scale of prices varying with costs. But the familiar sort of sliding scale works in the other direction, wages for example being made to vary with prices. The coal clause in this respect is analogous to cost-plus-a-per-cent contracts—which are not generally conducive to economy and efficiency. It has the characteristic weakness of that scheme, in so far as it does not distinguish high cost due in part to mistaken purchasing policies, or low costs due to special efficiency, from such costs as are due to uncontrollable market conditions only.[64] The suggested use of coal-exchange prices would obviate this objection, if not so seldom practicable. However, the

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in advance the price to him of the service to be rendered." Hence, it decides adversely as to the application of variable rates, although the application of a coal clause to large electric-power consumers, who are able to calculate expenses, is not considered objectionable. In December, 1920, the three largest New York City electrical companies announced their intention to extend the application of a coal clause to all consumers. Probably this policy is more due to the need of additional revenues than to any conviction of the intrinsic suitability of this rate device to consumers of small size. An injunction appears to have been obtained against this measure (Electrical World, Mch. 19, 1921, p. 675).

[63] 1917 N. E. L. A. Convention proceedings, general volume, pages 183-4.

[64] The Public Utilities Commission of the District of Columbia, on September 3, 1920, while granting increased rates to the Potomac Elect. Power Co., rejected a proposed coal clause for wholesale contracts. The Commission says it "is convinced that the company is entitled to an increase in revenue, due principally to the increase in the cost of coal. . . . . A coal clause such as that suggested . . . . is objectionable inasmuch as there is less incentive to secure coal at the most advantageous price when it is known that the cost, whatever it may be, is automatically passed on to the consumer."

cost theorists of the commissions will not be frightened by such a consideration and, indeed, its bearing on the coal clause is comparatively unimportant.

It is of interest to note that one company (Metropolitan Edison of Reading, Pa.) adopted or proposed to apply a *wage* clause, effective September 16, 1918, applying the above discussed principle also to this element in cost.[65] The basic wage rate is the average hourly scale in effect Aug. 1, 1918. Rates for electricity are to increase one-half of one per cent for each one cent per hour increase in wages, and similarly for decreases.[66] Increases or decreases are to be ascertained monthly and to be the basis of next month's charges. The analogy of the above to the ordinary coal clause is practically perfect. Its application to all rates, not merely the power rates, is logical, though it would be pertinent to examine carefully into the variation or absence of variation in the share of wages in total cost for each of the different rate clauses. No other wage clause has come to the attention of the writer, hence its mere mention in the present connection as cognate to the coal clause.

There are questions of public policy involved in such a wage clause, involving the fixing of prices to be paid by consuming third parties through an agreement between employers and employees, that need not be discussed here.

Coal clauses have been in large part war or war-prices emergency measures. One might therefore suppose them to be a passing phase of electrical rate-making.[67] Such is not the view of the writer, nor does it appear likely that the public service commissions will in general adopt that position.[68] The coal clause contrib-

[65] 14 Rate Research 211. This device does not appear to have continued in use.

[66] The method is inaccurate unless the per cent refers to a constant base rate.

[67] Thus the Pennsylvania Public Service Commission has said that coal clauses "should be superseded by more definite rates carried into the tariff schedule." State Belt Elect. Ry. Co. *v* Pennsylvania Utilities Co., August 12, 1919. 16 Rate Research 13. But in another case it refused to abolish an existing coal clause. P. U. R. 1919F 635. In a later case it says coal and labor clauses should be eliminated. P. U. R. 1920B 380.

[68] Compare the following expression of the Committee on Public Utility Rates of the National Association of Railway and Utilities Commissioners: "It is suggested that in order to save the utilities from the frequent necessity of coming to the Commission as increased costs of materials and labor may make it necessary, that percentage increases or decreases based on unit cost increase or decrease for fuel and for operating labor would most satisfactorily meet this situation where the various State Commissions have adopted uniform cost accounting for the public utilities." Proceedings of the 30th Annual Convention, 1918, page 217.

utes a desirable element of flexibility to revenues and involves a better adjustment of rates to fuel costs where the margin tends to be close. Attempts to make the coal clause general, however except as a temporary substitute for generally higher rates are to be judged differently.

### Further Points, and the Uncompleted Task of Description

The actual complexity and variety of existing electrical-rate schedules is no more than suggested by the foregoing description and comment.* When the rates themselves have been deciphered there sometimes remain to be considered various riders, applying especially to wholesale contracts, which often affect the variation in the price charged for electricity.

The use of a per cent surcharge for all rates (or even for selected rates) does not affect the rate structure and calls for no discussion. This device has been adopted by companies and commissions as an emergency measure, either with the expectation that prices would shortly recede so that it could be withdrawn, or as a means of immediate relief pending a general upward revision of rates. Its employment for all the rates of a company—unlike that of the coal clause— may be taken to imply that existing rate differentials are acceptable, or at least tolerably satisfactory.

A noticeable element in rate schedules that is not discussed, because not distinctive of electrical rates and not in its nature so much a price-making as a payment-compelling device, is the prompt-payment discount. In all comparisons of rates this discount can be properly disposed of by deducting it and making the comparisons on the net basis. The delayed-payment penalty, which is comparatively rare, is in principle the same, but this eliminates itself from comparisons.

The absorption of the prompt-payment discount into the regular rate, or the extra-provision for it where there formerly was none,

* The Rate Research Committee of the National Electric Light Association has been for some time occupied with the compilation and standardization of electrical-rate forms and schedules. Its annual reports, published in the Convention proceedings, together with the periodical Rate Research, issued under its direction and devoted to similar matters, including abstracts of articles and decisions, offer a great range of material for the study of rate theory and practice. Still more important is the N. E. L. A. Rate Book (annual from 1917) and its supplements, containing in condensed form the electrical rate schedules in force in practically all considerable sized cities in the United States and Canada. Statements made in this book as regards the degree of prevalence of various rate types and practices have been made to conform to the data there given.

has lately sometimes been employed as a means of increasing revenues.

It is of interest to note that sometimes the prompt-payment discount, so called, becomes in fact, through an increase of the percentage for the larger demands, a quantity discount. Since the commercial credit of the larger consumers is presumably better than that of the small ones, and the cost of collection less for the former, and since the prompt-payment discount is a collecting and credit device, such a use of it is in effect false labeling.

A type of rate seldom used and difficult to classify, but economically interesting, is the "output rate," under which a consumer (who is of course a manufacturer of some sort) is charged according to his units of output for processes using electricity, as, for example, an ice-making plant according to tons of ice produced. Kilowatt hours per ton of ice, it should be noted, are not constant but vary greatly with the load and capacity factors of the ice plant. This plan introduces the ability-to-pay element into something resembling the energy charge. In this respect it is like the demand charge based upon assessed value of premises,[70] and not unlike certain ways of applying the Wright type of rate.

The device of optional rates—not only a precautionary aid to experimentation, but if skilfully used, sometimes an important means of self-classification—is discussed later in considering class rates.[71]

Special contracts between a public utility and individual large consumers, though having a term of years to run, have been held by the courts to be a part of the rate structure and subject to revision by public utility commissions. Such a consumer may be entitled to special consideration, rather than to specific performance under the contract, if he has made expenditures and commitments adapting his premises to central-station service or done anything involving a consideration for the contract.

Most of the details that might receive further attention are not important, in the sense that they are not to be reckoned with as permanent elements in the electrical rate situation. It has been the plan of this chapter to emphasize what has shown itself to be

[70] See page 64, above.
[71] Page 114.

permanent and what contains promise of further development. But there is a danger of misrepresentation in thus picking and choosing, even where one attempts to be fairly comprehensive.[n] The evidence of what is to come that is afforded by the recent or present dominance of one or another method or practice among the leading electrical companies ought, so far as possible, to be set before the student in full for such use as he can make of it.

There is still much experimenting with new rate devices to be looked for, and it will be a long time before there is substantial uniformity of rate types throughout the country. Inertia, if nothing else, will long preserve the remains of present fundamental differences between the rate schedules of various companies. But the general tendency henceforth will doubtless be toward simplification and at the same time toward uniformity.

[n] Brief descriptive data showing the significant facts about the rate schedules of the most important electrical companies in the United States presented in tabular form would be highly valuable. The difficulties of such tabulation are not few. The N. E. L. A. Rate Book meets the need to some extent. Where differentiation is so important, averages for consumer classes are worth little. Indeed, comparisons of such averages might serve well to illustrate the limitations upon their significance. On the other hand, the reduction of the facts to tabular form is essential for convenience of comparison.

## CHAPTER III

## THE REIMBURSEMENT OF SEPARABLE OR PRIME COST

Importance of separable or prime cost. Only two rate elements closely related to it.

*Output cost—the kilowatt-hour, minimum.* Inexactness of any separation. One cent per kilowatt hour ordinarily more than separable cost. The residual method of analysis not applicable. The kilowatt-hour element most likely to be heavily loaded with general costs.

*Consumer cost or initial cost of service.* Relation to extension and to intensification of use. Taxing the adjacent class for initial cost. Relation to a low kilowatt-hour charge. Proper amount of a consumer charge. Rural extensions. Comparison with gas. Possible limitation upon the combined rate. Politics involved in the maximum rate. Lamps a special question.

*Lamp efficiency in relation to the service charge.* Recent great progress in lamp efficiency. Slowness of the adjustment of rates to this situation. Carbon filament lamps are economically obsolete. Discontinuance of free renewals desirable. The general employment of a service charge would largely solve the problem.

*The meter charge the preferable form of service charge.* Best especially when there is no demand charge, as is proper for the small consumer. Meter capacity actually a function of demand. Graduation of the meter charge. Encouragement to liberal use of kilowatt hours. Prevention of discrimination against the intermediate class. The annual basis of the usual minimum charge objectionable. No question of meter rent. A two-charge rate is not complex.

There are certain costs so definitely caused by the service of this or that consumer that any system of charges at all conformable to sound economics or to ordinary sentiments of justice will obtain reimbursement for at least these costs from the consumers immediately involved. The preceding review of electrical rate elements, if not common knowledge of the theory and practice of rate-making, will suggest that general carrying charges for fixed capital are not among these separable costs. Such expenditures are made as part of the general outlay necessary to the undertaking and are only secondarily or ulteriorly to be considered in determining whether a particular customer or class of customers is worth having. They are not a part of the prime cost directly due to the service of a specified individual or class.

From among the rate elements above passed in review, it is easy to select two that relate especially to the reimbursement of separable cost. These are the initial or service charge and the kilowatt-

hour charge. As regards the latter, however, since it is likely to be the principal feature of any sort of rate, it usually provides for much more than separable cost, sometimes, indeed, for all cost and profit. For this reason the upper limit of the magnitude of the separable kilowatt-hour element in cost, not to speak of average separable kilowatt-hour cost, cannot be inferred from actual rates unless the other elements are otherwise provided for.

### Output Cost—The Kilowatt-hour Minimum

In order to determine the amount of the separable kilowatt-hour element in cost by a formally correct scientific method, it would be necessary to find for a given plant under usual operating conditions the extent and character of the variation in unit cost per kilowatt hour in relation to the variation of the total quantity supplied. Such an investigation would give the separable or variable cost per kilowatt hour. In order that the figures might have general scientific interest, however, it would be necessary to compare results obtained in the same way for many different plants. The degree of adjustment of equipment to operating conditions and resulting degrees of efficiency obtained constitute one important element in the problem. Such a difficult statistical (and possibly in part experimental) study has never been made. When obtained the conclusions would be subject to various qualifications. Furthermore, such a study is not indispensable, since an approximate or probable minimum figure will serve sufficiently well the purposes of rate-making where the kilowatt-hour element will be used to carry much besides the separable kilowatt-hour cost, as it practically always does.

If it can be shown that one cent per kilowatt hour will (or would before the War) more than provide for all strictly separable kilowatt-hour costs, it is evident that the essence of the problem of electrical rate-making—at least for the great majority of consumers, in fact all but the very largest—is found not here, and probably not in any other aspect of separable cost, but in differentiation. But it is not difficult to show that actually one cent per kilowatt hour will take care of the kilowatt-hour separable cost under ordinary circumstances, with a qualification only as regards the distribution element in cost, which might have to be minimal rather than typical.

A sizeable and well-managed electrical plant not unfavorably located has production costs less than one cent. Total operating expenses per unit may go above two cents, but that includes maintenance, which is mainly of the nature of a carrying charge, and also most of the consumer costs, as well as such general expenses as are variable per kilowatt rather than per kilowatt hour. A modern and efficient street-railway power plant not unfavorably located does not show expenses (even with maintenance in some cases) for power operation, including distribution, as high as one cent per kilowatt hour. Power is commonly sold by electrical companies to street railways and by street railways to one another at less than a cent a kilowatt hour, even where there is no separate demand charge. Most rate schedules of large electrical companies contain rates providing for sales to very large consumers of certain blocks of energy at one cent or less per kilowatt hour, though this commonly holds only for the later blocks under a scheme of quantity discounts on the block principle and is presumably supplemented by a demand charge. These, and similarly low off-peak rates, doubtless show something above separable kilowatt-hour cost. There are also cases of step rates dropping to one cent or less.

Coal clauses in various rate schedules carry as mathematical implication a definite kilowatt-hour cost for fuel. Derived normal fuel costs are, or for the earlier coal clauses were, 1 to 4 mills per kilowatt hour. In general fuel accounts for more than two-thirds or about three-fourths of production expenses in a modern steam plant. It is doubtful whether any other element in cost varies as definitely per kilowatt hour, though a qualification is necessary, even as regards fuel. The most liberal allowance for such elements could scarcely raise the total generating expense to more than a fraction of a cent, if at all strictly computed as separable and as variable per kilowatt hour.

Altogether it is evident that, if all other expenditures could or should be otherwise reimbursed, it would be quite consistent with the fullest regard for separable kilowatt-hour cost if the kilowatt-hour element in the rate were computed at as little as one cent per unit. Load-factor considerations and capacity costs are another matter, having no relation to the kilowatt-hour separable cost that is under consideration here.

However, the above comparisons are based mostly on before-the-war conditions and are subject to qualification on that account. But if it be necessary to modify the conclusion so as to make the figure less than 2 cents, instead of as little as 1 cent, per unit, the general perspective is not essentially changed.

It should be noted by way of caution that neither the kilowatt-hour nor any other element or part of cost is determinable by what may be called the method of residuals, which consists in separating or apportioning by some means the costs attributed to certain other elements (or to classes of consumers) and then assigning what is left to the kilowatt-hour element (or to some residual group of consumers). This procedure calls for mention here because, among the various rate elements, the kilowatt-hour element is usually, and doubtless in general correctly, treated as the residual rate element, that is, as the one most suitable to take care of costs not otherwise apportioned. But one's attitude towards this residual method cannot be so tolerant when it is applied to load otherwise unapportioned costs upon a residual class of consumers, that is, upon the small consumers. This is commonly the outcome of the "increment cost" argument. It is not safe to compute what would be the additional cost of taking on a large consumer and give him a rate barely in excess of such cost. The analysis should deal with classes in any case. And the "with and without" test is logically just as applicable to those already served—whose consumption may also be in the balance in certain respects—as to additional business. The whole question is one of taking advantage of elasticity of economic demand and the "increment cost" argument cannot be confined to a particular individual or a particular situation without tending to cause unjust discrimination.

As to the reasonable ground for burdening the kilowatt-hour charge when in doubt, the practice may be referred to the greater readiness of the consumer to pay in proportion to service rendered. The preferences or the prejudices of the consumer are an important factor in determining what the traffic will bear.[1] Our con-

[1] The following expresses the different view of a central-station man: "*Any cost which does not vary with the kilowatt hours sold or with the number of customers connected is a demand cost.* In other words, unless you can definitely assign a cost to the customer group or to the energy group, it belongs to the demand group." The reasons given are financial. The view is that of Alexander Dow. See 1916 N. E. L. A. Convention proceedings, general volume, p. 428

clusion as regards this phase of the separation of cost is rather negative, that is, the kilowatt-hour element will usually take care of so much besides kilowatt-hour separable cost that in actual rate-making all one needs to consider is merely that if the exigencies of the situation had happened to favor cutting the kilowatt-hour charge to separable cost and in case of doubt burdening other rate elements, rather than it, the kilowatt-hour charge might easily be much lower than it is likely to be made. It matters little for present purposes whether two cents instead of one will often be necessary to cover variable energy cost. The kilowatt-hour charge is seldom calculated with reference merely to reimbursing for separable cost.

Illustrative examples of the results of analysis of cost for electricity according to underlying variables and possible rate elements are given in Chapter V, page 125, below.

### Consumer Cost or Initial Cost of Service

The nature of consumer cost and the various ways in which it may be dealt with have been indicated in the discussion of rate elements. That such costs are separable per consumer or per some related unit is not open to question.

Any sort of initial charge—and such is the essence of a service charge—operates as a discouragement to the potential consumer, especially if small, who might otherwise become a customer of the company, and, even though at first no more than paying expenses, ultimately a profitable one. The indirect effects of a policy that restricts business are always worth considering. The fact that large consumers often grow into such from small ones is probably of less weight than the effect of familiarizing the public generally with the use of electricity for all sorts of light and power service. There is no reason why electricity should not in time come to be thought of as a necessary of urban life, just as gas now is. It may be maintained that it is bad economy for practically all residences to be supplied by both utilities. But gas will doubtless continue to be needed for cooking and, for the rest, it is simply a question as to whether gas lighting or electric lighting is superior as regards cheapness and convenience.

There are too many questions as to the proper basis of comparison between gas and electricity as regards cost and serviceability to the consumer to make it practicable in this connection to put the facts into terms of dollars and cents. For electricity we should probably assume the use of 50-watt tungsten lamps, perhaps also some of smaller size and less efficiency, but not at present of gas-filled lamps. On the other side, are we justified in assuming the general use of incandescent mantles, and, if so, must we also suppose the more costly high candle-power gas to be used with them? Supposing the consumers' premises piped and wired for both gas and electricity, and supposing small use of incandescent gas mantles, electricity is the cheaper illuminant as well as preferable on general grounds of convenience and sanitation.

But under any sort of initial charge the comparison is affected by the amount of energy taken. It is clear that, with a service charge for electricity and with none for gas, the latter would be the more economical for the very small consumer. But in the case of all consumers above the very smallest the advantage of electricity over gas should be decidedly increased by a correspondingly lowered rate per kilowatt hour.

The slightest consideration of consumer cost leads to the conclusion that there is somewhere a lower limit of size below which it is unprofitable for the electrical company to get the business. If the company serves this class at a straight kilowatt-hour rate, it must be granted the right to make up the excess cost somewhere else. It seems logical to take the compensating profits from the next largest class, especially if the members of the smallest class get their service at less than cost because of an initially level kilowatt-hour rate, which will naturally be extended to neighboring size-classes. If, on the other hand, the company is protected against the undue extension of this kind of business by some sort of an initial charge, the kilowatt-hour rate can properly be much lower. Even if the smallest class still does not entirely pay its way, there is no reason why the initial kilowatt-hour charge should be affected by this fact, though the excess cost, if important, must be made up to the company somewhere, perhaps by a generally slightly higher kilowatt-hour charge.

The width of the first block under a simple kilowatt-hour rate is a test of the extent to which the consumer of moderate size is

made to suffer because of the failure to have a separate initial charge and a two-charge rate—or possibly of the extent to which he suffers from a low legal maximum. The arbitrary nature of the determination of the limit of the first block is reflected in the fact that its width ranges from 10 to 1000 kilowatt hours a month.[2] Obviously such differences are not results of differences in cost.

If consumer cost is taken care of by some kind of initial charge, the initial kilowatt-hour rate should be correspondingly lower.[3] Let us suppose, for example, that the initial rate be reduced from 10 to 6 cents per kilowatt hour. Such a change is bound to have an important effect upon the liberality with which electricity is used by those who will readily pay consumer cost by way of a separate charge. Not only will the average size of this group of consumers be increased by some of the very smallest consumers being cut off, but the remaining small consumers will tend to use energy more liberally, not only for lighting but also for power, cooking, and even heating purposes. This should be of decided advantage to the company as well as to the community generally. The two things the electrical company especially needs are evenness of load—which means diversity of use—and density of consumption—which means that any district (a residence district, for example) worth cultivating should be cultivated intensively. An initial charge, with the rest of the rate schedule appropriately adjusted to it, cuts both ways.

But it is clear that the initial charge should be made as small as may be, consistently with its purpose to take care of consumer cost. In other words, only *prime* or separable consumer cost should be included. For this reason the writer would, at least in a very large city, exclude the cost of service pipe and wires from any computation to determine this element in the rate. The cost of connecting an apartment house containing fifty families with a street main is no more separable, and chargeable to the individual consumer, than are the wires stretched along a block-front to supply 20 private houses. In a city of multiple dwellings, the distribution system extends almost to the meter and its cost is a joint cost.

[2] N. E. L. A. Rate Book, checked to 1920 issue. Auburn, N. Y., 13c. for the first 10 kw. hrs.; N. Y. Edison and United Elect. (New York City), 7c. for the first 1000 kw. hrs. York, Pa., shows 20c. for the first 5 kw. hrs. and 8c. for the next 200.

[3] Where a municipal council had not provided for a minimum charge, the Ohio Public Utilities Commission (*re* Cleveland Elect. Illg. Co., P. U. R. 1920B 891) said "the maximum rate must necessarily be sufficient to cover the most expensive short-time service."

There are various opinions as to the normal amount of consumer costs, but it is the common opinion that $1.00 per month per consumer or less will cover them. One dollar is in fact rather large—or was large prior to the War. It may be appropriate for detached houses considerable distances apart—for suburban or rural conditions—[4] but not for multiple city dwellings. Often some element of fixed charges on the distribution system is included, and it should not be. And service pipes and wires belong with the distribution system in the case of multiple dwellings. Thus qualified and explained, 50 cents per month may be deemed at least a fair standard of reference.[5]

Rural extensions of electrical service involve heavy costs per consumer analogous to most of the elements of the service charge with added emphasis on the cost of physical connection, transformer and transformer core losses. The cooperative building of lines by farmers has sometimes been adopted to meet some of these costs. In this case density cannot be made to help.

[4] The Indiana Commission considers $1.00 the reasonable minimum charge in the country corresponding to 50 cents for the city. Decision of August 7, 1916, 9 Rate Res. 391.

[5] The following tabular statement comes from the testimony of the Commonwealth Edison Co. of Chicago, on which basis in part the Illinois Public Utilities Commission approved a minimum charge of 50 cents a month. See its decision of June 26, 1916; also 9 Rate Research 248. The statement happens to be even more directly indicative of the nature and proper amount of a consumer charge and is here reproduced chiefly with reference to that view point.

SUMMARY OF THE CUSTOMERS' COST (INCLUDING ALL ITEMS ON CUSTOMERS PREMISES)

| | Cost per— annum | Cost per— monthly |
|---|---|---|
| Fixed charges on first cost of watt-hour meter | 1.03 | .086 |
| Fixed charges on cost of first supply of incandescent lamps | .23 | .019 |
| Meter reading, billing, bill delivery, bookkeeping, claim and statistical | 2.01 | .167 |
| Meter installation, removal, maintenance and testing | .90 | .075 |
| Inspection on customers' premises | .20 | .017 |
| Customers' repairs, including household devices but excl. meters | .34 | .028 |
| Fixed charges on service connection | .41 | .034 |
| Maintenance of service connection | .15 | .013 |
| | $5.27 | $.439 |
| General expense, such as office rentals, telephone, telegraph and general supervision at 15 per cent of the particular expenditures listed above | .79 | .066 |
| Total Customer's cost | $6.06 | $.505 |
| Energy used by average customer whose bill is less than 50 cents | 1.84 | .153 |
| | $7.90 | $.658 |

There are some opportunities for economy in the matter of consumer costs that ought perhaps to receive more attention than they do. In the summer of 1917 the Detroit Edison adopted bi-monthly billing for small consumers with a view to cutting one of the most important items of expense.[6] Where it is the practice to require deposits of consumers, it would seem to be unnecessary to make monthly meter readings and collections. The practice of billing quarterly is not unknown in Europe.

Gas consumer costs are comparable in character with those for electricity. The comparison is of special significance because, with the small consumers overwhelmingly preponderant, the possibility of avoiding the issue by shifting the burden to other classes of consumers is substantially taken away. But gas rates and the prevailing size of gas bills—$2.00 a month for all classes of consumers in New York City—do not suggest that the consumer element in cost approaches as much as $1.00 a month.[7] Such is the situation as regards gas consumer cost absolutely considered. It is true, on the other hand, that material costs, which are represented sufficiently well by production expenses, are greater for gas. It appears that production expenses constitute nearly two-thirds of gas operating expenses and only half as large a proportion of electrical operating expenses. Fixed costs, also, are decidely greater relatively in electricity supply. The necessary charge per thousand cubic feet is therefore bound to be comparatively large and there is accordingly less reason for making a separation of other cost elements from the thousand-cubic-feet (corresponding to the kilowatt-hour) element, even though, absolutely considered, gas consumer costs are not very different in amount and are of more nearly universal significance for the business done than for an electrical company.

On general grounds already discussed, that is, in order not to discourage the accession of new consumers, there should be no objection to limiting the combined kilowatt-hour and initial (or consumer) charges to some defined kilowatt-hour rate. As expressed

[6] Electrical World, July 14, 1917, page 68.

[7] In 1908 the average bill for gas in New York City was $24.93 per year and for electricity, $177.34. In 1915 the first average had fallen slightly, to $23.66, and the second considerably, to $101.78. For the data, see the 1915 Annual Report of the New York 1st District Public Service Commission, Vol. III, pages 22, 24. Some uncertainty as to the possible inclusion of a few public consumers in the number compared with revenues from private consumers does not significantly affect the results.

graphically in a rate curve, such a proviso means that the first part of the curve in Figure 1 will cut horizontally straight across the diagram at perhaps 12 cents or at whatever other level may be fixed. This will mean some small loss to the company to be made up elsewhere, but the policy is justifiable on both the general grounds mentioned at the opening of this section. Moreover, such a rule is sometimes necessary in order to conform to laws prescribing a legal maximum. The argument in behalf of such a use of the maximum idea is exactly the same as the argument for having a maximum at all. At worst it is a concession to public opinion that costs comparatively little. The Wright type of load-factor rate is the result of an application of similar reasoning to the demand charge.

The fixing of a *low* maximum rate per kilowatt hour, where this is the only element in the rate or where the limitation applies to the average kilowatt-hour charge regardless of how it is computed, is, however, a somewhat different matter from leaving intact an established or customary kilowatt-hour maximum that is not so low as to cut the ground from under the argument for a compensating reduction of the kilowatt-hour element in the rate when a service charge is added. The charge for initial and small consumption under a straight kilowatt-hour rate is usually the point in an electrical rate schedule that is, economically speaking, least open to objection as being too high. Politically, however, that is, with a view to the number of voters affected, it is evidently the most vulnerable. This fact may have something to do with the tendency to make reductions at this point rather than elsewhere. Not only the commissions but also the companies appear to be affected by such considerations.[a]

[a] A reduction in the maximum rate for the New York Edison Co. from 10 cents per kilowatt hour with lamp renewals included to 8½ cents with lamps, or 8 cents without, was effected May 1, 1915 (1915 N. Y. 1st Dist. P. S. C. R. 58). The opinion of Commissioner Maltbie favored a greater reduction in the kilowatt-hour charge and the establishment of a meter charge of 50 cents up to $1.00 a month additional (1915 N. Y. 1st Dist. P. S. C. R. 132). This is the constructive feature of the opinions in this case. The real issue of the case, discrimination through large quantity discounts, was not met. But private plant interests are not the best protagonists of the small consumer. About the 1st of November, 1916, a further, and nominally voluntary, reduction was obtained from the company, promising 7½ cents as the maximum from January 1, and 7 cents from July 1, 1917.

None of these reductions appreciably benefit the intermediate class that can neither use the isolated plant as a club nor swing elections by its votes. The 1911 block charges were so adjusted (some of them raised) in 1915 that the general rate consumer of intermediate size, after allowance for the option of supplying his own lamps, remained substantially where he was before, the reduction on 1000 kilowatt hours consumption being $1.00 and on

The claim for reduction of rates on general economic grounds is strongest for consumers intermediate in size, perhaps small as regards connected load but comparatively long-hour users. A wide initial block may easily be made to deprive them of the possibility of any reduction from the maximum rate.[9]

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1500, $1.50. Beyond the latter point the rate was somewhat lowered. In the reduction of Jan. 1, 1917, increases in the block charges between 1200 and 2500 kilowatt hours monthly about balanced the reduction on the first 900 kilowatt hours. A similar statement applies for the July 1 change. The gist of this situation is that mere size as such is not allowed to benefit the consumer until he approaches the competitive class. These compensating features of the changes in the average-rate curve, however, should not be taken to mean that there was any corresponding balancing of gain and loss in the revenues of the company. There was of course a very considerable cut.

In the Brooklyn Edison case the view of the Commission is indicated by the following quotation (1916 N. Y. 1st Dist. P. S. C. R. 175,228): "The minimum bill now in effect serves many of the uses of a meter charge or consumer charge, and the practice of the company may, therefore, be left undisturbed." This, and other parts of the opinion, show progress towards a position favorable to the service charge and thus to preparation for meeting the issue of discriminatory quantity discounts squarely on its merits.

The opinion and order in the New York and Queens Electric Light & Power case (1917 N. Y. 1st Dist. P. S. C. R. 87)—which company is an intercorporate associate of the New York Edison—bears on the views of the Commission on this subject. It results from a compromise accepted by the company. A meter charge of 60 cents is instituted in combination with a kilowatt-hour charge of 9 cents, but the resulting combined rate is limited to 11 cents a kilowatt hour, except that a minimum charge of $1.00 a month is retained. The restrictive clauses are accepted provisionally for the time being, and the opinion expressly favors *substituting* the consumer charge for the minimum charge.

A later expression of opinion by this Commission is as follows: "For the present the Commission approves a minimum charge, reserving, however, for future consideration the question as to whether a fixed consumer charge should not be adopted by the Flatbush Gas Co., as well as by other electrical companies, in place of the minimum rate. Of course any question of a future change in the direction of imposing a fixed consumer charge would necessarily involve a readjustment of the energy charge to which it is to be added" (Feb. 1, 1918). P. U. R. 1920E 930, 1020.

The N. Y. 2nd Dist. Commission decidedly prefers the consumer or service charge to the minimum charge, for good reasons given, as appears, for example, in a quotation in the Electrical World for Jan. 15, 1921, page 172.

[9] On this subject a recent opinion of the Missouri Commission (*in re* Fort Scott & Nevada L. H. W. & P. Co., P. U. R. 1915F 540) is much in point: "These rates . . . . result in a uniform rate of 10 cents per kilowatt hour to residence consumers, except, of course, as to those whose accounts are not paid by the 5th of the month, and to those who fall within the minimum monthly charge. This result is due to the extremely large blocks, starting with 100 kilowatt hours for the first block. No residence consumer uses more than 100 kilowatt hours per month . . . . consequently, no residence consumer participates in any of the lower rates on the sliding scale. The blocks appear too large also for business lighting, and the size of the block militates against the very purpose of block rates on a sliding scale . . . . limiting unduly the proper effects of long hours' use of electricity and minimizing the encouragement of long hours' use."

It should be noted that the objection is to a first block one-tenth as large as that of the New York Edison Co. On reducing the maximum in 1915, the width of the first block was extended by this company from 250 to 900 kilowatt hours, and further to 1000 kilowatt hours a month on July 1, 1917, making it, so far as one can determine from an examination of the 1917 N. E. L. A. Rate Book, absolutely the largest initial block or step in the United States. The usual size of the initial block under block rates is 50 or 100 kilowatt hours a

Lamps are a separable element in cost usually provided for in some one or another rate element, but now perhaps more generally made a separate and optional part of the service of the electrical company. As regards the carrying charge on the initial and continued investment in lamps on behalf of a consumer—if the company owns them—that is properly a part of consumer cost. It is separable per consumer (with a qualification as regards the size of the installation) and may be so treated in the company's rates or left to the consumer to attend to directly. Maintenance and replacement of lamps—depending as they do chiefly on hours' use, the number of hours a lamp will burn being fairly constant—vary with kilowatt hours consumed and are properly covered by the kilowatt-hour charge. The constituents of lamp cost are thus, after sub-division, separable on two different principles. But the lamp situation is a special question. It is best disposed of neither by sub-summing lamp cost under consumer cost nor by separately apportioning the costs involved between this and other rate elements.

### Lamp Efficiency in Relation to the Service Charge

Consumer cost is significant chiefly for residence consumers and therefore for lighting more than for power uses of electricity. The straight kilowatt-hour rate has long been open to criticism as an inadequate method of dealing with the cost of supplying the small consumer. It is easy to see that the situation has not been improved by the remarkable increase in the efficiency of electric lamps of small sizes. Such efficiency is ordinarily expressed by the number of watts required per candle of illuminating power. In no other respect has electrical engineering made such marked progress in the last decade or so [10] as this of lamp efficiency. Further improvements are to be expected. If the benefits of those made are already extended to consumers lately using obsolete carbon-filament lamps,

month—so far as the word "usual" is applicable where practice varies so greatly. There are more cases under 50 than above 100. The residence rate in Philadelphia effective April 1, 1916, is of the quantity-block type with a first block of 12 kilowatt hours a month at 9 cents.

[10] In his President's address on the "Trend of Electrical Development" (Proceedings of the American Institute of Electrical Engineers, September, 1915, pages 1491-1502), Paul M. Lincoln makes various comparisons for the fourteen years preceding, with the seventeen years following 1898. His result for lamp efficiency is 1000 per cent improvement for the later as compared with 50 per cent for the earlier period. Other comparisons, and the general results, though striking, do not involve acceleration of growth.

that is only because the War was the last bale of straw that broke the back of inertia.

Some of the peculiarities of electrical rates resulting from the lamp situation have been noted in the section on Lamp Renewals in Chapter II. The readjustment of rates with a view to encouraging the use of tungstens generally—whether by requiring their supply and free renewal in consideration of the rate for energy or otherwise—is but recently, if as yet, accomplished. There is, of course, the difficulty of reduced kilowatt-hour revenues.

The making of lamp renewals a separate matter should mean the gradual achievement of the universal use of the most efficient lamps.[11] The consumer needs to learn to judge and compare the efficiency of electrical appliances. It may not be worth while as yet to install tungstens for some of the less frequently used lamps or those much subjected to jarring movements.

On the other hand, we should not too readily assume that the drawn-wire vacuum tungsten is the last word in efficiency and serviceability, even for the domestic consumer. The extent to which tungstens have already displaced the less efficient types is shown in a previous chapter.[12] Comparatively few carbon-filament lamps are now issued. But if the revolutionary potentialities of the vacuum tungsten lamp have already been realized, there remains the possible application of the gas-filled lamp in the domestic field. The supply companies are not yet through with the effects of increasing efficiency in lamps of small sizes.

A simple computation will show that under no practicable kilowatt-hour rate will the obtaining of a given amount of light from carbon-filament instead of tungsten lamps be other than a considerable economic loss at prevailing differences in the cost of the lamps. Carbon-filament lamps were obsolete by 1916 and ought to have been scrapped as promptly as possible. A qualification of this proposition with reference to the few lamps that are so seldom used that the carrying charge is the most important element in cost, however, should be mentioned. The general statement also relates

[11] In the Brooklyn Edison opinion and decision of November, 1916, the N. Y. 1st District Commission proposed a separate charge of a half-cent per kilowatt hour for lamps, tungstens of 50-watt size or other equally efficient lamps to be furnished. In the compromise finally accepted by the Commission the company leaves the consumer to supply his own lamps without this option.

[12] Chapter II, page 75.

primarily to purchased electricity and is more to the point where the kilowatt-hour element in the rate bears the whole burden of cost and profit. A company producing its own electric energy, a street railway for example, may find it economical to use carbon-filament lamps, because kilowatt hours are for its purposes valued only at their separable cost. Also, because the company is usually not the ultimate consumer of the light it furnishes, it may consider that a lamp is a lamp, with little regard to how much candle power the public enjoys.

The very remarkable increase in the efficiency of incandescent lamps, including the small sizes suitable for domestic use, constitutes an important argument for a meter or similar service charge. The reduction of the quantity of energy needed to obtain a given amount of lighting to little (if any) more than one-third of what it was 10 years ago involves a greatly increased relative importance of such costs as do not vary with the kilowatt hours consumed.[13] The separate recognition of these costs should benefit the companies by making possible the conservation of their income from lighting consumers, and at the same time this policy should make it feasible for them to do their share in promoting the general use of the high-efficiency lamps. A company can scarcely be expected to give to the public the full benefit of scientific advances in this particular when every step in that direction decreases revenue without bringing about any comparable reduction in expense.[14]

With the development of small tungstens that are slightly more costly but much more economical of energy than the old carbon-filament lamps, a part solution of the resulting problem confronting electrical companies may be the discontinuance of free lamp installations and renewals, thus leaving the consumer no excuse for not using the most economical type of lamp and at the same time giving the company some slight compensating benefit for such a

[13] Average lumens per watt in 1907 were 3.33, and in 1918, 10.30. Page 241 of the 1919 N. E. L. A. Lamp Committee report.

[14] "Until the probable limit of development [of high-efficiency lighting] can be more fully predicted, or until the growth of other applications of service makes the lighting demand of incidental importance, the central station's fixed service [kilowatt hour] and demand charges must be protected by the rate schedule." 1912 report of the Rate Research Committee, N. E. L. A. Convention proceedings, 1912, vol. 1, page 195. At the 1916 N. E. L. A. Convention, President E. W. Lloyd summed up the situation as follows: "We find ourselves practically through the period of change from the carbon lamp to the high-efficiency types of incandescent lamps, the increasing use of which has lowered the use of energy for lighting purposes in the last few years." See general volume of proceedings pages 10-11.

lessening of consumption as may result from higher lamp efficiencies. In connection with any change in maximum rates, it is a simple matter to give to all consumers the option of either paying (say) half a cent a kilowatt hour for lamp renewals or purchasing their own lamps.

The other part-solution indicated is the adoption of some sort of service charge, and with it promotion of diversified and intensified household consumption. It is possible that now (at the close of 1920) time has to a great extent solved the particular problem of the electrical company involved in the transition to the use of high-efficiency lamps by small consumers; or that the increase of general efficiency and the increasing importance of power uses has permitted it to be merged and lost in the general problem of new cost levels made acute by the War. Even so—if the critical phase is now passed—so much of progressive development of the opportunity to provide intensive service for domestic consumers depends upon a proper disposition of consumer cost as related to initial use for lighting that the need of a correct solution of the problem cannot be too much emphasized.

### The Meter Charge the Preferable Form of Service Charge

What the form of the initial charge shall be must be decided largely with reference to whether there is to be a separate demand charge. For reasons to be given presently, the writer believes that, except in the case of large consumers, there should be no such demand charge. Under such circumstances it is evident that it would be well so far as possible to have a kind of initial charge that will also to some extent serve the purpose of a demand charge. Of the three possibilities open—the consumer charge, the meter charge, and the minimum charge—the meter charge is the one that has special advantages from this point of view.

It is possible to class both the initial charge and the demand charge under the general head of readiness to serve. The principal difference in form is that the initial charge attaches to the consumer as such, or substantially so, while the demand charge varies quantitively with the consumer's active connected load or some related quantity. From this point of view the meter charge partakes of the character of both, since there is an additional charge for additional meters, and there may also, and should reasonably, be higher

charges for the larger sizes of meters. The theory of the meter charge is different, but its effect in relieving the kilowatt-hour charge may be substantially the same in character as is the proper effect of the demand charge. The meter charge, however, requires no elaborate measurements or estimates of kilowatt demand. Its basis, which is the prime cost of the service of the individual exclusive of energy taken, is different from the basis of the demand charge, which is the fixed charges imposed upon the company. It does cover some fixed charges, but it does not explicitly take account of load-factor considerations. In fact, however, as regards small consumers the latter are usually not directly taken account of even in such rates as purport to do so, but instead some quantity having a direct relation to the *connected* load, in place of the maximum demand, is made basic.

It happens that meter capacity is a function of maximum demand just as much as is connected load. If the sizes of meters are carefully adjusted to the needs of the consumer and if their capacity is measured in watts, meter capacity is in fact rather more directly related to maximum demand than to connected load. So far as lights are used alternatively to each other—as to some extent even between dining room and living room—the meter need not be adjusted to aggregate connected capacity, but only to something considerably smaller. This situation might be used as an argument for making the meter charge heavy enough for it to relieve the kilowatt-hour charge to a greater extent than it will when based upon prime cost. It is, at any rate, a strong argument against making the meter charge relatively smaller for the larger consumers, at least where the kilowatt-hour rate is at the same time graduated down somewhat with reference to volume of consumption. From this point of view, care should be taken to graduate upwards the meter charge. It should not be allowed to deal merely with the initial cost of the small consumer, on the assumption that it will be relatively negligible for large consumers—until a sufficiently large sized and otherwise sufficiently distinct type of consumers is reached for them to be entitled to a different type of rate.

As to the scale of the meter charge, as has already been set forth, 50 cents per month for a consumer having a single meter of the smallest size class would seem to be (or to have been, before the War) the appropriate round number under ordinary conditions in

a large city. For detached residences the appropriate charge may be nearer $1.00. Care should be taken in such cases, however, not to mingle density-factor with consumer-cost considerations, especially if the former can be dealt with in other ways. But it is not the purpose of the writer to draw the line with exactness between meter or consumer cost and other cost elements, if indeed it is necessary under a differential system of rates to do so. The charge for additional meters should be at the same rate as for the first. For larger sizes, the charge should be increased, probably in relation to wattage, or possibly to amperage.[15]

The situation as regards high-efficiency lamps has a relation to the position here taken that the meter charge is preferable to the minimum charge. If the company is reimbursed for consumer cost, it is thereby freed from important checks upon the extension of business where it should be extended and not elsewhere. If, on the other hand, the consumer feels that what he pays *per* kilowatt-hour is *for* kilowatt hours, his attention will be called to the economical use of energy, not only negatively in the sense of using as little as may be per service unit (per candle hour, for example), but also positively in the sense of extending its use under encouragement from a low kilowatt-hour charge by adopting additional electrical appliances. The kilowatt-hour charge will naturally be less of a check upon consumption when accompanied by a meter charge. This, it is true, is an advantage of the meter-charge only over the minimum-bill method, not over the consumer charge. In relation to the last the advantage of the first method is rather a matter of the need of some substitute for a demand charge, having a least educative value.

The adoption of a consumer or meter charge seems to be about the only way of avoiding discrimination in dealing with the small consumer. Otherwise there is opportunity for debate as to whether the companies suffer directly more from the costs per consumer not fully compensated as such, or gain indirectly more by keeping kilowatt-hour rates unduly high for a broad range of small consumers, usually including long hour users.

[15] The cost of the meter, which is the most important single element in a consumer charge, may be ascertained from the price lists of the manufacturers, but the appropriate discounts should be applied. The 5-ampere meter is by far the predominant size. After adding the cost of installation, as in its nature also a capital charge, the investment in the meter of a small consumer is (or was before the War) perhaps $10.00.

As a method of insuring the company some return for the service that is rendered apart from kilowatt hours supplied the meter charge is preferable because it has a direct and consistent relation to cost. Even as regards the concession made to public prejudice under the minimum-bill method by allowing the consumer to take kilowatt hours up to the amount of such bill without affecting the total amount charged, thus making it appear that it is at his option that he pays for kilowatt hours that he does not receive, that fact, after all, is not much of a consolation where, for example, the consumer may have been out of town. It would seem to be better to take pains to educate the consumer through the meter charge as to the nature of the cost of electricity—incidentally obtaining other advantages—than to have the initial charge accomplish but a single purpose and that crudely.[16]

The minimum bill will naturally be larger than the consumer or meter charge because it takes care of initial kilowatt hours as well as of consumer costs, though of the latter only very roughly. The fact that it is absorbed in the kilowatt-hour charge, however, makes the roughness of the adjustment less noticeable and less objectionable to consumers.

In the above discussion of the minimum-bill method of dealing with consumer cost it is assumed that the minimum charge will be upon a monthly rather than an annual basis. In actual practice the latter basis is commonly preferred.[17] In effect, this exempts

[16] The first report of the Rate Research Committee of the National Electric Light Association unanimously approved the minimum-bill method, that is "minimum charge per month or per year." See Convention proceedings, 1911, vol. 1, p. 318. But the alternative the Committee has in mind is the unqualified meter rate. Its recognition in this reference of the important bearing of high-efficiency lamps on the situation is significant. The recommendation of the minimum bill is reiterated in 1916 (Convention proceedings, general vol., p. 222).

[17] The situation at the close of 1916 as regards opinion and practice in this respect is summed up by the Committee on Public Utility Rates of the National Association of Railway Commissioners as follows: "In a few cases only have commissions considered the question of yearly or monthly minimums. The Massachusetts Gas and Electric Commission in the Boston Edison electric case ordered a minimum charge to be adjusted on an annual basis, so also the New York 2nd District Commission in the Buffalo electric case, and the Maryland Commission in the Baltimore case. The New York 2nd District Commission said, 'The minimum rate [*sic*] should be a yearly minimum and not a monthly minimum. The proper proportion should be charged monthly, however, and an adjustment made at the end of the year.' The New Jersey Commission said, 'That the making of this [minimum] charge by the month is just and reasonable and is really more equitable than if the charge was made by the year.' The Wisconsin Commission said, 'As to whether the minimum bill should be placed on a monthly or yearly basis much can be said on both sides. In the instant case,

from the charge any consumer who takes (say) $12 worth of current a year, regardless of whether his consumption is spread evenly through the year or is disproportionately large in winter (and at peak times) and too small in summer to pay the consumer costs that are about equal through the months of the year. The point is of course interesting in principle rather than practically important. A separate meter charge does not so readily lend itself to such an ineptitude. In effect such a minimum charge upon an annual basis amounts merely to a guaranty of $12 a year from each consumer, and properly relates to contingency rather than to separable cost.[18] In dealing with the large mass of small consumers the supply company needs no such guaranty, since in the mass their behavior is entirely regular and predictable. Only in the case of a very large consumer, whose individual demand appreciably affects the business of the company, is such a safeguard necessary. The strictly monthly basis of the minimum charge may, however, be objectionable owing to temporary disconnection in summer to save the amount of the charge. So far as it seems desirable any sort of initial charge may be modified upon due notice for absence of the consumer from his premises.

Seasonal and intermittent consumption might, it would seem, be properly dealt with by an initial charge collected for an entire year without regard to amount consumed. Under such circumstances, however, the situation is correctly met by modifying the service charge to make it chiefly a charge for installing and renewing the meter. The indicated charge, due to this special cost, would be less than the annual consumer cost (12 months) and more than

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however, it seems advisable to leave it on a monthly basis.' " 1916 Convention Proceedings, page 102.

"Of the 138 cities in the United States having a population of 40,000 or over, minimum bills are monthly in 90, yearly in 11, variable in 8, and daily in 1. Twenty-four of these cities have no minimum bills and four are not reported." Page 105. The significance of these returns, however, is not entirely clear.

The committee specifically recommends the yearly basis (page 102). Its reason for this position (apparently) is contained in the following statement: "When the actual consumption for the year exceeds the sum of 12 minimum bills it is thought that adjustment should be made on the ground that the object of the minimum bill has been secured."

[18] The minimum charge may serve the purpose of a demand charge—properly of course only where the only other element in the rate is the kilowatt-hour charge—though less well than the meter or consumer charge. The annual basis does not entirely conflict with this conception of its function. Compare the view of an early advocate of the minimum charge (on an annual basis): W. J. Greene, A Method of Calculating the Cost of Electric Current and a Way of Selling It, Electrical World, Feb. 29, 1896, p. 222. In a Maryland case (P. U. R. 1918E 331) the monthly basis is justified on readiness-to-serve grounds.

the consumer charge for a single month. Where a consumer's deposit is not provided for, there should be no objection to collecting an amount corresponding to such a charge in advance.[19]

It is scarcely necessary to insist that the charge per meter is not to be considered a charge for the use of the meter, or a meter rent. It is merely the best species of service charge and a method of obtaining reimbursement for separable consumer cost in general. The meter is installed directly in the interest of the company and not for the use and enjoyment of the consumer. There is no reason why he should pay *rent* for it.[20]

Doubtless one reason why the minimum charge is commonly preferred by both companies and commissions over the meter or customer charge—either of which involves a separate rate element—is its apparently greater simplicity. There is less arithmetic required to compute the bill. With a consumer charge the rate cannot, even conditionally, be stated in a single figure. But if it is in the interest of the consumer to make this rate element explicit, the fact that he is not habituated to it should not be allowed to stand in the way. Simplicity is not possible without honesty, and honesty demands that consumer cost be made explicit. There is a kind of simplicity of rates that serves the purposes of monopoly. Economic, not political, considerations should determine the character of dealings with the small-consumer and numerous-voter class. Viewed with reference to what a two-charge rate accomplishes, the adjustment is decidedly simple. A two-charge rate is in its nature as simple as a Wright rate or a quantity block rate, except

[19] But, says the New Hampshire Commission (Claremont gas company case, March 22, 1919), collecting a service charge for a year in advance is *not* reasonable, and it suggests a discount for payment in advance. 15 Rate Research 222. The New York 1st Dist. Commission (Richmond Light and Railroad, June 4, 1919) disapproves a meter installation and renewal charge of $5.00 to be refunded if the consumer continues to be such for an entire year, but intimates that it would approve such a charge if absorbed when a certain quantity of electricity had been taken, instead of being made merely a matter of time. 15 Rate Research 380-2.

[20] The following from the opinion of the New Hampshire Commission in the Concord gas case is significant and correct, though it just misses the point made above: "It was claimed that it is the duty of the gas company to furnish meter and equipment for measuring gas as much as it is the business of a grocer to furnish scales for weighing out goods for his customers. . . . The difference which is controlling is that each gas consumer has a meter on his own premises, which is reserved for his particular use and can be used by no one else, whereas the same scales are used by a large number of customers, and it would be impractical to make a charge to each customer, though of course the use of the scales is paid for by the users . . . . as truly as if it were made a special charge to each individual customer. 13 Rate Research 250.

for the somewhat sinister fact that the latter are commonly so designed that most consumers have no practical acquaintance with anything except the first block.

It should be noted that the meter charge as favored by the writer is not a third rate-element but is, instead—as will appear in Chapter V—regarded as in part a substitute for the demand charge in the case of the small consumer, for whom, because of administrative costs or discriminatory incidents of the methods in use, it is considered undesirable to attempt to apply load-factor rates.

There is a further aspect of the argument for simplicity. The dealings of the supply company with the consumer should have regard to keeping consumer cost as low as possible. The making of lamp supply a separate matter is a step in this direction. The prepayment meter may assist. The practice of requiring a deposit might be so developed as to make the reading of meters and collection of bills oftener than quarterly unnecessary.

Although the minimum-bill method is more generally employed by electrical companies at present, there appears to be a definite tendency towards the more specific service charge.[21]

Dynamic economic considerations, or regard for progressive development of the uses of electricity, favor the employment of the meter or consumer charge as against the minimum bill. Load-factor considerations suggest the meter rather than the consumer basis. It is more important that consumption be diversified than that small consumers for one use only and without elasticity of economic demand be served extensively at less than their separable cost. But a small consumer who is potentially a larger consumer obviously does not belong in this class. And no consumer whose patronage is in doubt should be loaded with uniformly pro-rated fixed charges. This is the topic next to be dealt with.

[21] The Committee on Public Utility Rates of the National Association of Railway Commissioners says: "The trend of opinion at present seems to be to some extent towards a 'service charge' instead of a minimum charge." 1917 Convention Proceedings, p. 455.

## CHAPTER IV

## CLASS RATES AND RATE-DIFFERENTIATION

Classification the most familiar means of differentiation.

*Meaning of "differentiation."* Price differences not its essence. The unequal loading of fixed charges and overhead costs, in place of pro rating them, the essential point. Graduation may be without differentiation. In a variety of modes differentiation is the gist of the electrical rate question.

*Class rates, especially the power rate.* Most electrical rate classification is based upon load-factor considerations. Competitive sources of power not important for small users. Long hours' use and daylight use. The latter now of little importance in large centers; residence lighting less on the peak. Permanent advantage of power relates to seasonal variation. Grounds for a class power rate are no longer strong. Disadvantage of power in respect to the "power factor."

*Class rates in general.* Employment to stimulate new and developing business, but with favorable load characteristics. High-tension current in effect a different article. Occupational classes. True and consistent use classification impossible. Distinctness and definiteness of classes necessary for equity. Weakness of reliance upon average characteristics. Value of optional rates as a means of self-classification. The option belongs to the consumer. Class rates not an advanced type.

*The justification of differential rates.* Commercial success of differentiation not sufficient. Possible costliness to society. Differential rates should be based upon adequate cost analysis, which takes account of future conditions and possibilities. Breadth and volume of service fundamental. The principle of "charging what the traffic will bear" too nearly akin to that of taxation to be proper for private business. "Value of service" not a definite guide. Use-value classification impossible for electricity.

Questions relating to the share of separable cost in electrical rates having been disposed of, the more characteristic and important element in the situation, namely, rate differentiation, is next to be considered. This chapter will deal with a familiar, and indeed the most obvious, mode of differentiation, which is classification. This method is employed by the railroads especially, and is generally recognized as typical of differential price-making. But first there is need of stating what is meant by the term.

### Meaning of "Differentiation"

If by differential rates one means a diversified and complex system of prices, including differences not conformable to the quantities of commodities and services dealt in as these are physically

measured, it is evident that electrical rates are decidedly differential in a variety of ways. The classification of service and the making of different rates per kilowatt hour for the different classes so constituted is only the most obvious mode of differentiation. The purpose and effect of such "class rates" are to be considered in the present chapter. But the mere existence of such price differences is not the essence of differentiation, and it is important to understand the fundamental character of the latter before attempting to pass judgment upon this particular mode of differentiation.

By differentiation the writer does not mean the mere making or existence of systematic differences in price, even when such differences are based upon something other than differences between the goods or services for which compensation is received—though this is a familiar external aspect of differentiation. The essential fact is rather the disregarding of separable costs and of the arithmetic of aliquot parts in the apportionment of fixed charges with reference to their recovery from consumers. Stated positively, it is the *loading* of such costs unequally (as opposed to uniformly per commodity unit or per objective service unit) upon the various classes of consumers, such loading having reference to increasing the volume of business transacted rather than reference to collecting "full compensation"—whatever that may mean— for the entire cost of each article sold or service performed. Separable costs should be repaid by each consumer, but joint, general, or overhead costs, may be differentially distributed, so that some contribute much and others little. This practice is contrasted in idea and method with *pro rating,* where the result is a matter of physical facts and simple arithmetic, instead of being a matter of commercial policy.

Differentiation may be accomplished by the simple graduation of rates. But if the graduation conforms directly to the variation of cost, as it is generally supposed to do in the case of wholesale prices, the rates are not differential in spirit and should not be so named. At least such a case should be qualifiedly described as external differentiation. True, it is impossible in practice accurately to draw the line between the two, but clear thinking requires the recognition of differential rates and graduated rates as distinct and different things, even though one may sometimes be

in doubt as to whether a particular rate belongs more in the one or the other group.

The various modes of differentiation are nowhere more comprehensively represented than in electrical rate practice. The legal and administrative status of the three modes to be considered—classified service, quantity discounts, and demand charges—is well enough established, though most public-utility commissions show some reluctance to meet the general issue squarely. That issue—the problem of determining what degree of differentiation is justifiable in principle and what are the practicable ways of applying the principle—is the gist of the electrical rate question. Even in such phases of electrical rate-making as are commonly assumed to be founded upon hard and fast analysis of cost, we shall find the real question to be whether this or that peculiar feature or element of a rate schedule is an organic part of a well considered differential policy or not. But classification, as the most familiar mode of differentiation, is first to be considered.

### Class Rates, Especially the Power Rate

The classification of customers according to the use to which the energy is put, or according to occupation, is a common feature of electrical rate schedules. The analogy of freight classification by the railroads immediately suggests itself. The basis of freight classification is, in no necessarily invidious sense, "what the traffic will bear." The same principle, of course, finds expression in the classification that appears in electrical rate schedules. There is doubtless some tendency by this means to encourage new uses of electricity and to initiate new classes of users. But this policy is more likely to find expression through pushing certain consumer's appliances. Altogether, use and occupational classifications have been based more upon load-factor considerations than directly upon the desire to expand business by such means.

The most important and most general application of the method of classification is observed in the distinction between lighting and power rates. This involves separate metering of energy used for motors and means in practice the concession of a lower rate for such a use than for energy not thus separately treated. In the same way a special rate may be granted for storage-battery charg-

ing. The power rate is old and, where the distinction is still justifiable, must be referred mainly to load-factor considerations or to the supposed long hours' use of the maximum by motors.[1]

It is possible that something might be made of a claim that it is necessary to give power users a low rate because of possible sources of power other than electrical. But in the case of power for small units, the superiority of electricity is so great that competition is not effective; and, in the case of very large users, the possibility of an independent supply is often no more important for power than for lighting. Indeed, even for the small lighting consumers there is an available substitute in the form of illuminating gas that might logically be expected to cause the electrical companies to favor that class of business. In some cases they very likely do as much as load-factor and other cost considerations permit. But it often happens that both gas and electricity are supplied by the same company or else by associated companies, under which conditions the electrical company may make no effort to extend its business among small consumers, leaving them to the associated gas company. Altogether, aside from load-factor consideration, the special power rate is traditional, rather than generally adapted to present conditions of electrical supply, at least in the largest population centers.

Unless there is something intrinsically advantageous in a class rate as compared, for example, with a load-factor rate—a question that does not call for discussion—the consideration of the power as distinct from the lighting rate in practice relates to consumers of small and intermediate size, since large consumers can be better taken care of by load-factor, and possibly by density-factor, provisions. In fact, distinctions between power and lighting are often not made at all in the case of wholesale consumers (unless on account of the power factor). In the matter of lamp supply, moreover, the large consumers are likely to prefer to attend to their own needs, even if the small ones do not. Hence the following

[1] The unnamed writer of the section on the Development of Electrical Rates in the 1916 report of the Differential Rates Committee of the National Commercial Gas Association (page 28) disposes of the origin and recent history of the power rate with the statement, which is perhaps too off-hand, that the power rate was originally started as half the lighting rate and that there have been two theories followed in its adjustment to changed conditions, one that the rate originally made contained a sufficient concession to "value of service," so that the lighting rate is gradually to be brought down to the power rate, the other that the 50 per cent ratio should be maintained in making reductions.

remarks deal with the power rate in relation to comparatively small consumers.

The most general argument for a distinct power rate, lower than the ordinary lighting rate, is the long hours' use of the power demand. It is, also, possibly still true in general, though of doubtful validity for the largest urban centers, that the daylight load is comparatively small and that therefore power can be taken on at very little cost per unit supplied. This argument rests upon the supposed diversity of power uses. In fact, however, the power demand is less likely to be off the peak than residence lighting, which constitutes most of the small lighting. Where the peak comes before six o'clock, residence lighting consumers are not more responsible for it than power consumers. But in most large cities, the winter peak does come before 6 and even before 5 P. M.[2] This situation is now developing further because of the much reduced consumption per candle hour of the most recent types of lamps.

If, owing solely to the great increase in the efficiency of lamps, the relative importance of lighting as a contributor to the system peak may soon become half what it has recently been, the tacit assumption of many discussions of electrical rates, namely, that the lighting consumers make the peak, will then become absolutely untenable. If small consumers at the same time come to apply electricity more liberally for motor and cooking uses, diversity among them will take care of their contribution to the company's load factor, so that not much direct attention need be given to this question in devising a rate schedule for them.[3] Even now there is not much ground left for making a distinction between small lighting and small power consumers. While the load-factor of the latter is better, the diversity of the former is not only better, but doubtless increasingly better. The diversity in question, however, has regard largely to diurnal variation.

Only as regards the seasonal variation of the load has power commonly a permanent advantage in comparison with lighting.[4]

[2] See the load curves above, pages 17, 19, and 22

[3] Even as regards lighting uses only, high efficiency and decreased cost favor a tendency to longer hours use. Cf. Williams and Tweedy, Commercial Engineering, page 73.

[4] In New York City, despite the power load of the electrical companies, and despite the probably somewhat greater extent of use of gas for cooking in summer than in winter, the seasonal variation of the demand for the two services seems to be substantially identical, its character being determined by the variation in the supply of natural light. See the discussion of this topic (with diagram) in the Annual Report of the New York Public Service Commission for the First District for 1914, vol. III, pages 72-78.

A load-factor rate of the Hopkinson type on an annual basis, which should be available for large consumers, will be duly influenced by this characteristic. Thus the large power consumers can be adequately provided for without separate classification. Neither Wright nor Hopkinson rates, if on a monthly basis, concede anything to power for its seasonal constancy. As regards small power consumers (and other small consumers), what seems to be needed is some concession on account of extra summer use. This, if desired, could be effected by granting a specially low rate on account of energy taken between April 1 and October 1 equal to or in excess of the average amount taken during the six preceding months. This would operate to encourage occasional heating and cooking uses, when fires are not regularly wanted, as well as summer power consumption. The seasonal variation is administratively much easier and simpler to deal with than the diurnal.

The fundamental distinction of electric-supply classification, that between lighting and power rates, is based upon load-factor considerations and also upon the assumption that the lighting demand will constitute the peak. This assumption no longer holds good in large cities under developed conditions of electricity supply.[5] We may in fact expect a gradual reversal of conditions under the influence of factors whose importance is already established. Moreover, if, or so far as, the favorable load characteristics of a consumer may be directly determined and recognized in the rate given him, the clumsier class-rate method should be regarded as a makeshift to be superseded as soon as practicable.

But if this statement is true of the most important of classificatory distinctions, then it is reasonable to suppose that the classification of service will gradually cease to be an important method of electrical rate-making, except possibly in small towns, being otherwise appropriate only for experimental and provisional rates designed to develop, and determine the characteristics of, some one or another kind of new business. However, whether the writer's

[5] Mere proportion between the two classes of use has much to do with the result. According to Williams and Tweedy (page 72), the other than lighting connected load rose from 26 per cent in 1892 to 50 per cent in 1910, despite the fact that the method of computation involves understatement. There has been a further marked change in the same direction since 1910.

forecast is justified depends, of course, entirely on the character of the reasoning and conclusions of the following chapters.[6]

It would seem that there is left no strong reason for a class rate favoring small power consumers in comparison with residence lighting consumers, especially if the rate schedule otherwise makes little or no use of mere classification. But it may still for a while be advisable in some localities for companies with an undeveloped power load to give to this class a better rate than that available for lighting consumers. An allowance for the non-supply of lamps is a matter of course and should not be regarded as constituting a difference in rates.

Power in one important general respect compares unfavorably with light, because the former is subject to business fluctuations, while the lighting use is fairly constant through bad times.

There is another important disadvantage to the electrical company that is special to the power load. The point is summed up in the words "power factor." This is a decidedly technical engineering matter of the nature of which only a hint can well be given here. For direct current, volts *times* amperes = watts. For alternating current volt-amperes are the equivalent of watts for lighting uses but not where the electric energy is transmuted into mechanical power. Hence a power user at a given wattage may require of alternating current generators, conductors and transformers nearly a third greater capacity than the kilowatts he employs and for which (directly or indirectly) he is supposed to pay. The power factor is the co-efficient that expresses the importance of this element in the situation.[7] It should be noted, on the other hand, that

[6] Compare the 1917 report of the Rate Research Committee (General volume of the N. E. L. A. Convention proceedings, page 181): "The Committee notes . . . . a general tendency towards the adoption of identical rates for small lighting service and miscellaneous power service. There is an evident advantage of obtaining the benefit of the diversity between the day service for power and the night service for lighting; thus securing a better utilization of the company's investment all the way from generating equipment to service and meter. The fact that the wiring may be arranged on a more simple plan is of distinct interest to the customer."

[7] The power factor has been defined above at page 13. A power factor of 70 per cent or a little better is fairly representative of operating conditions where no special effort has been made to improve it. The "wattless component" is, as has been noted, significant only in connection with the supply of *alternating current* for *motor* uses. Other than alternating-current generation is now unusual in up-to-date plants, unless very small. But direct-current distribution is often used in the more dense centers of demand, in connection with alternating-current generation. What sort of equipment comes between the prime-mover and the consumer's service connection is determined by complex considerations that are of tech-

careful voltage regulation is highly important for lighting (though less so for tungsten than for other lamps) and comparatively unimportant for power uses.

Engineering theory and practice favor correcting the power factor and penalizing for bad adjustment, rather than attempting to treat the matter as strictly a rate-making problem.[8] Methods of dealing with it are still in the experimental stage.

Aside from the distinctive character of power uses—whose distinctiveness is evidently subject to much qualification, and whose claims, also, are not indisputable—there are no classificatory distinctions in electrical rate schedules of constant and enduring importance from the point of view of any decipherable principle. Though something might be made of a policy of favoring the raw materials of manufacture, and thus of power as in general consumed productively, nothing of this sort is observable, though it might be alleged to be implied in wholesale rates, which however are actually in spirit merely competitive.

### Class Rates in General

Some class rates are doubtless designed to stimulate a new and developing class of business. Special rates for storage-battery charg-

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nological rather than economic interest, though possibly having an important bearing on the rate for power. The relation between kilowatt hours consumed and the necessary capacity of the generating and other appliances is in inverse ratio to the power factor of the consumer's apparatus.

The 1917 report of the N. E. L. A. Rate Research Committee contains the following: " The committee suggests, as a basis for discussion only, and not as a fully considered recommendation, that a satisfactory power factor rule should (a) accept without charge or penalty power factors from unity down to (say) 85 per cent; (b) increase the rate suitably for power factors from 85 per cent down to 75 or possibly 70 per cent; and (c) penalize by a rapidly increasing surcharge all power factors of 70 per cent or less." Convention proceedings, General volume, p. 185.

[8] 1917 Rate Research Committee report, page 186: " The sense of the Committee is that the best policy is to effectively penalize all unreasonably low power factors, and all costly unbalancing, and thus prevent their occurrence, rather than to measure the excess cost of these faults in our practice and endeavor to collect that cost from the consumer." Compare also an editorial in the Electrical World, Sept. 27, 1919, page 689, emphasizing *deterrence* and *cure*. The 1920 Rate Research Committee says: " It is the sense of the Rate Research Committee that loads of unreasonably low power factor and unbalanced loads on polyphase systems should be considered by member companies as interference with good service preferably to be prohibited, rather than as variable factors in the cost of service, to be compensated for in the rate charged "; and, further, if a power-factor penalty clause is adopted, the rate under it " should be such as to permit full compensation to the company, while affording inducement to the customer to secure correction of the low power-factor, or of the lack of balance."

ing are of this nature, though this use is also one with alleged specially favorable load and diversity characteristics. The same applies even more certainly with regard to refrigeration uses. In all such cases, however, the favored new class of business presumably has desirable load characteristics.

To certain very large consumers in position to use primary or high-tension alternating current a very low rate may be granted. It is asserted, and with reason, that this is in effect a different commodity from the low-tension current supplied to ordinary consumers.

The Wisconsin schedules furnish examples of rather detailed classification, chiefly occupational, based on load-factor considerations. In the Madison case[9] for incandescent lighting, classes A to F are distinguished according to the percentage of connected load to be deemed active, and in addition the percentage for class A (residences) is graduated.

It should be observed that such classification is of the occupation or business of the consumer rather than of the actual use made of the current. Accordingly residence consumers constitute a class by themselves, without regard to the great variety of uses to which electricity is put in the household. In fact the use classification that is the foundation of most differentiation, and of railroad rate-making in particular, cannot be consistently applied in electrical rate-making. The uses of electricity, if not exactly subjective, are in most cases very near to the satisfactions of the ultimate consumer. No method of classification can deal successfully with the different uses of a lamp socket from which the lamp is from time to time removed to be replaced by an electric flat-iron connection, presumably used for ironing, but which is also demonstrably practicable as a cooker, and which—if the present generation slept in unheated rooms—would doubtless be found superior (though to be used with care) to any of the bedwarmers our grandmothers used. The same lamp socket may also be used to run an electric fan, a washing machine, or a vacuum cleaner. In fact no scheme of classification according to anything that approaches final or definitive use can be consistently applied in electrical rate-

[9] 4 W. R. C. R. 747. The Wisconsin Commission, in its determination of percentages of connected load deemed to be active, consistently assigns high ratios for power.

making.[10] And if some practicable method could be devised, the desirability of diversity of use would condemn the policy as regards small consumers especially, and would make its wisdom doubtful even for large ones. With large consumers use classification can be carried out, but only by the employment of separate meters, by frequent inspection of consumers' premises, etc.

A related difference between railroad and electrical rates that calls attention to a further difficulty with use classification in the electrical field consists in the fact that railroads in handling freight do business with dealers instead of mainly with ultimate consumers. Dealers are familiar with differential practices and will seldom object to the principle, as distinguished from unfair or vexatious applications of it. The electrical company, on the other hand, comes into conflict with the moral sense of the consumer when it tries to discriminate between uses that are all mere varieties of the application and enjoyment of a homogeneous supply of energy that is administered by the consumer himself.

In order that rate classification appeal to the general sense of justice, it must avoid arbitrariness. This means that the lines of division between classes should be distinct and definite and that they should leave no room for doubt as to the class in which a consumer properly belongs. The problem is simply the very general one of putting like things together. While it does not necessarily follow that there should be no attempt at classificatory separation where grades shade into each other, it is evident that much care should be taken with distinctions of this sort. If two classes do shade into each other by practically continuous steps, the character of the change in the rate should be of a similar nature. The superiority of the block over the step type of quantity-discount rates rests upon this principle. While the step rate is distinctly a class rate, it might be argued that the block type represents an abandonment of the class-rate principle. However, this may be regarded as merely a matter of definition. Nevertheless, the weakness of the step rate

[10] The classification of a motor-generator set used to operate a moving picture machine has been the occasion of confusion in the minds of some commissioners. The energy bought is applied directly to operate a motor, but it is *used* for lighting. The N. Y. 1st District Public Service Commission decided that the classification should be as power (1916 N. Y. 1st Dist. P. S. C. R., 162). Montana and Illinois Commissions decided that the ultimate use governs, while the latter recognized that the long-hour service may constitute a claim for a lower rate. 1917 Rate Research Committee Report, page 182.

in this connection is a weakness of class rates generally. The group for which a special or class rate is made should, for the best results, be definite and easily distinguished—a distinct type of consumer or of use.

But the conveniences of the electrical companies (or the necessities of the case) cause *averages* to be the main reliance in devising class rates. A large group of consumers is ranked according to its average standing, in particular as regards the average hours' use. For example, on the average, saloons made a more intensive use of their installations than grocery stores. Would it not be better, however, to let the rate vary with actual performance within each class? Some grocery stores surpass others and some of them may surpass some of the saloons in respect to the amount of electricity used, for example, per foot of floor space. A class rate based on averages is not economically speaking dynamic in its effect; it does not stimulate intensive use. It is not even quite fair as between consumers thus lumped together.

It is worth noting that such rate classes based upon averaging may be worse, or more discriminatory, than step-rate classes, because it is only near the class boundary that injustice occurs under step rates, and the injustice may be made practically negligible by the employment of numerous small steps and the narrowing of the range of each class. In the case of class rates based, for example, on occupation, it is quite possible that most of the members of a class have load factors—supposing the underlying principle of the classification to be of this nature—nearest to the type for other classes that obtain higher or lower rates. If a step rate is properly considered as by nature discriminatory,[11] the class rate is ordinarily more so.

Rate schedules often show "optional" alongside of regular rates, that is, under certain conditions consumers may choose whether they shall be charged under one rate or another. Where the straight meter rate is long established and general it may be well to permit (rather than compel) the consumer who is in position to respond to encouragement towards long hours' use to be billed under a load-factor rate, even though it would not be advisable to attempt to put

[11] Cf. page 47, above

into effect for small consumers generally any such rate.[12] The exercise of such an option amounts to self-classification, hence its mention in the present connection. Such a method of constituting classes is in principle thoroughly sound. If the rate schedule is honestly made up and only reasonable limitations are put upon the exercise of options, discrimination is practically eliminated. Difficulties with drawing the lines between classes do not exist. There is no arbitrariness. If two consumers with identical characteristics are found in different classes, this situation does not result from acts of the company. The consumer can take advantage of a change in his conditions of consumption by promptly changing his class. He may be definitely stimulated to a more intensive use in order to avail himself of a load-factor option. Optional rates are also serviceable to the company as a means of experimentation with new adjustments and of acquainting the public with new devices.

Carelessness on the part of the company may involve an abuse, namely, a customer may be not duly informed of his right and interest to exercise an option that is undoubtedly to his advantage. The company has a duty to perform in this connection.

Whether a customer should be allowed to exercise his option after the fact, that is, with reference, for example, to a month just passed, is another question. For reasons of administrative convenience, in general he should not. And he should not be allowed to shift back and forth between rates at frequent intervals. However, any restrictions upon the choice of the consumer should be clearly stipulated and not a matter of afterthought on the part of the company. All the optional element properly rests with the consumer until he is given due notice of a change.[13]

This brief review of certain methods of differentiating rates by way of the classification of service is important chiefly as indicating the impossibility of arresting one's attention and interest, whether practical or theoretical, at this aspect of the matter. Systems and methods of classification point chiefly to load-factor considerations.

[12] The 1917 Committee on Public Utility Rates of the National Association of Railway Commissioners says: "A block rate meter schedule should be supplemented by an alternative [optional] demand schedule." Convention Proceedings, p. 453.

[13] An option cannot be withdrawn by the company without due notice. A New York 2d District decision on this point is given in 14 Rate Research 332.

which constitute the principal distinctive characteristic of electrical rates, or to quantity discounts, which are by no means peculiar to this field, but which are peculiarly important and significant in it. If it is practicable to make such load-factor considerations explicit, it is obviously better to do so, thus not only making the basis of rates clearer to the public but also more efficiently obtaining for the company the benefits of cost analysis and differentiation. It is assumed that classifications will not be employed to conceal the real objects of the rate schedule, though there is a danger that a company will deceive itself as well as the public in this way. A manager is not any more disposed to change an established classification merely because he does not understand it.

Classification, however, will doubtless remain a permanent characteristic of electrical rate schedules. It will appear conspicuously in the form of the schedule in the different rates offered. Such kinds of rates have been frequently mentioned. Even though classification be made to serve an administrative purpose—as it should mainly in distinguishing between the scheduled kinds of rates—rather than that of rate differentiation, the element of differentiation will seldom be entirely absent. Classification by way of optional rates and with reference to new appliances and situations will also continue. In this connection there are more positive, and not merely administrative, reasons for its being.

## The Justification of Differential Rates

There can be no doubt as to the commercial success of differentiation in rates. Of course it must be understood that excessive differentiation, or unjust discrimination—such as is not justifiable in the long run on broad economic, not merely commercial, grounds—is not in question. The American people have now reached a stage of economic and administrative experience where it is perhaps not necessary to argue for the commercial expediency of the policy of differentiation. But it is also not enough to prove that much. Differentiation must be justified from a social point of view if it, or some part of it, is to stand. Survival does not always mean the survival of the fittest. "Getting the business" is not sufficient evidence of correct policy.

Differentiation is, among other things, a competitive device. Since it is of interest primarily in relation to public-service corporations and since a public-service enterprise is now in general protected from competition through another enterprise of the same kind entering its field (as distinguished from competition between different kinds of enterprises), the fact that differentiation is a competitive device means that it ought to be carefully watched and often subjected to restraint. The device is too powerful to be left to unrestricted employment in the service of private interests and ambitions. What is profitable to a particular corportion may be costly to society.

The most obnoxious and unmitigatedly objectionable form of costliness to society is closely connected with disregard of cost analysis on the part of the corporation charging differential prices, hence this phase of differentiation can be adequately discussed with direct reference only to cost conditions. It is sometimes alleged that differentiation means serving some consumers at less than cost and in compensation obtaining excessive profits from other classes that are unable to help themselves. This allegation may mean that the critic is unwilling to recognize as just any but an objectively uniform and unvarying rate per unit supplied. In this case the criticism deserves little consideration. It involves the patent fallacy that an average, in this case average unit cost, is something objective instead of being the result of computation, or at least that the average is necessarily a type or mode, from which there are few except narrow and insignificant variations.

It is true, however, that the ambitious management of a corporation will, in its desire to expand and to "get the business," often do just the kind of thing that it is accused of doing, though the fault consists not in practicing differentiation as such, but in overdoing it. The means by which we are to determine whether there is error and injustice of this nature are cost accounting and cost analysis. Hence the importance of what they teach with regard to differentiation. The implication is that differentiation must be limited by cost. This may seem paradoxical, since to many it seems that basing rates upon cost can only be alternative to letting them be differential.

If by cost analysis is meant cost accounting, then we have here properly only a check upon differentiation, not its negation, and

certainly not its basis. It is true that cost accounting has reference to price making and that it allocates all costs. But so far as it is allocation according to some arithmetical or other formal rule, it has not the same character or effect as the actual separation or causational isolation of certain expenses to be attributed to a specific product. The very name "overhead" charges suggests that they cannot be separated. Of course they can be allocated on some basis of theory and experience, but that is another matter. Were cost accountants willing to (or expected to) deal with less than total expenditures, so far as they claim to obtain the actual cost of a particular good or service, their true service might be more clearly perceived and therefore greater.

If the reference is to cost analysis, there is no reason why the effect of business yet to be obtained upon aggregate and unit costs should not be fully considered, or rather, there is every reason why it should be "taken into account." It is in fact just here that differentiation takes its rise. But this kind of cost analysis may be correct in theory and yet wrong in its application. It is wrong in its application where a very low rate is extended to an individual large consumer on the ground that, during the term of the contract made, the "out-of-pocket expense"—the practical man's term for prime cost—will be less than the return received. The rate must be generalized and offered to all in this consumer's class, both as a matter of sound business method and as a public obligation, and the rate should be planned with reference to continuing it next year and into the indefinite future. Such consideration may reveal a weakness in the original calculation. It may appear that the effect of the additional consumer's demand upon reserve capacity may not have been sufficiently taken into consideration, or that maintenance cost may not have been accurately dealt with. The special bane of this kind of cost analysis is the tendency to let numerous unconsidered expenses be loaded on a residual non-competitive class of consumers[14] who are made to bear the burden of the mistakes

[14] For example, in an apportionment of expenses between consumers by a company that alleged its profits came from the large consumers, practically all taxes were loaded on the residual class of comparatively small consumers, although in the state in question the taxation of public service corporations was so adjusted that the amount of their taxes varied directly with profits.

made by a hasty management that over-reaches itself, but is protected from the natural consequences by its possession of monopoly power, especially over the small consumer. It is here that unjust discrimination, or unjustifiable differentiation, is especially likely to enter.

It is true that if, with an existing investment, additional large customers can be served who will bear their full share of the output costs and at the same time bear a part, at least, of the fixed cost, it is not unjustly discriminatory to give such large consumers a low rate.[15] The logic of this "additional business" basis is sound, but its application may encounter pitfalls. Even apart from mistakes of judgment as regards the incidence of future costs, a distinction should be made between capacity reasonably needed for present service but not fully utilized (in off-peak hours particularly) and reserve and excess capacity, which may not properly be chargeable to the needs of regular consumers.[16] A company should not be allowed to make *any* sort of rate merely because it is necessary in order to "get the business." The limit of differentiation is not determined by any such consideration. Rate discussions emanating from the electrical companies seldom show full appreciation of the importance of this fact.

Variation of cost is the controlling consideration in rate-making. A certain fundamental point is therefore likely to be lost sight of in following the mazes of more or less mathematical cost analysis. What the consumer wants and is willing to pay for is *service*. This attitude should have an important influence upon the policy of every public-service corporation. The amount of the charge should be determined with reference to increasing the quantity of service, that is, after the consumer has reimbursed the company for the separable costs he imposes upon it, the differential element in the charge should be mainly so determined. The greater the service, the more willing the public is to see the company obtain large revenues and large profits. The policy of small proportionate profits on large sales is properly applicable to the business of a

[15] Wisconsin Railroad Commission in Coleman-Pound Light & Power Company case, Sept. 29, 1919. 18 Rate Research 276. Similarly, Massachusetts Department of Public Utilities, Athol case, P. U. R. 1920C 1033, 1040.

[16] Maine Public Utilities Commission, Bar Harbor & Union River Power Co. case. P. U. R. 1920B 513.

public-service corporation, as of course to mercantile enterprises generally. For operating expenses and circulating capital this implies a quick turnover, and for fixed capital a high degree of utilization. This policy is quite the opposite of charging what the traffic will bear in the sense of charging all it will bear. The service rule means: In case of doubt favor the policy that means greater service.

As to the measurement of service—kilowatts of demand, except where the important matter is the insurance of continued supply, are not such a measure. In relation to the meter charge, also, it should be remembered that the meter serves the purposes of the company rather than those of the consumer. But the collection of meter and consumer costs separately should mean a freer use and greater service from kilowatt hours, once the small initial obstacle is overcome, hence there is a strong service argument for such a charge. Whether this is outweighed by the service counter argument, resting on the tendency of such a charge to restrict the extension of use to new small consumers, is elsewhere considered. The strongest claim for the kilowatt-hour charge as a comprehensive basis of rates is the fact that it is a service rather than a cost unit.

But, for the commonest use of electricity, there is a higher order of service unit or one more completely of that character, namely, the candle hour. The electrical companies ought to favor the use of the most economical lamps in a way they have not always seen fit to do. The adoption of a sort of demand charge for the small consumer that will facilitate the general use of high-efficiency lamps may thus itself be defended on service grounds. There is also a great field for the extension of use of electricity as an illuminant in the homes of the wage-earning classes. Comparative studies of *per capita* consumption should reveal to the electrical companies great fields of service which they have as yet hardly touched.

It should be evident that the above views are not at one with the so-called "value of service" theory. That phrase seems to the writer to be an ambiguous and, as used by practical men, rather "highfalutin" way of indicating a policy that includes unjust discrimination as well as justifiable differentiation.

If it is true that public-service corporations must be expected to take from consumers according to their ability to pay or accord-

ing to the companies' effective power to collect—which is one meaning of the value-of-service theory—if, in other words, they exercise a power akin to that of taxation, it would seem that mere regulation can hardly suffice to guard the public interest. It is coming to be recognized that the taxing power is a suitable means for correcting in some degree a certain tendency to malformation in the distribution of income. It is also alleged with reason that discrimination by monopolistic corporations has done a good deal to cause the existing undesirable degree of concentration of wealth and income. The power to redistribute wealth is not one to be delegated to private corporations.

If the value-of-service theory be taken to mean that rates should be determined, not by cost to the central stations, but by what it would cost the consumer to obtain the service elsewhere, then it is merely a superficial justification for competitive rates that involves any concession to the bargaining power of the large consumer that is necessary in order to get the business. Though concessions must be, they cannot be justified in this way, nor their proper limits so determined.[17]

[17] The 1914 Report of the Rate Research Committee incorporates a paper prepared under its auspices championing the value-of-service theory (N. E. L. A. Convention proceedings, 1914, Commercial Sessions volume, pp. 70-93, with discussion extending to p. 115). It pays its respects to the cost theory as determining the necessary general average of rates or the fair return, but its author or authors seem to think that cost analysis does not, even in part, provide a basis for determining what the different charges to different classes of consumers should be. The conception of value of service is the purely commercial and competitive one mentioned in the text above. But all the paper really attempts to do is to show where a differential policy is indicated according to the "value" principle. The results of cost analysis would not be different. As regards the degree or quantity of differentiation permissible—the real crux of the matter—nothing is said.

An older and better statement of the value-of-service point of view (though not offered as such) made by the Boston Edison Co. (quoted in the 24th Annual Report of the Massachusetts Board of Gas & Electric Light Commissioners, p. 24) is as follows: "The costs of an electric lighting company are actually the sum of what its customers' costs would be if they supplied themselves under the different conditions under which they consume current, less such deduction as is justified by the use of the same plant by different customers [load and diversity factors], and such deduction as is justified by the greater economy of the company's larger plant [density factor]."

In order to understand the practical significance of the value-of-service doctrine, it is necessary to take into account an unmentioned proviso. If the central-station manager wants to get a particular class of business, he feels he should be allowed to charge what the traffic will bear, in the lower-limit or lower-unlimiting sense of this phrase, in order to get it. And he wants to get the large consumers. Electrical companies generally are charging small lighting consumers more than the traffic will bear. For example, there were 224,000 consumers of electricity supplied by New York City companies in 1912 as compared with 1,323,000 consumers of gas, the ratio being 1 to 6. Or if meters in use by consumers constitute a better basis of comparison, the figures are 267,000 and 1,390,000, respectively.

Classifications of consumers are likely to have reference to "value of service" in a somewhat more objective sense than either of those just mentioned, that is, to classification of uses. The distinction between power and lighting is the first stage of such a classification, but the principle may be carried much further. Doubtless this is the most general form of differentiation, or most generally recognized form, outside the electric-supply industry, and it is especially familiar as freight classification. Because of the peculiar interest of the load factor for electrical rate-making, though this classificatory method finds considerable scope in practice, it has a subordinate place in electrical rate theory. But its borrowed prestige, as well as its practical importance, make it necessary to point out its objectionableness in this connection, more especially because use classification may appear to be an application of the service principle above stated. The point may be brought out by emphasizing the differences between the electrical and the railroad rate situation. In the latter case the nature of freight and of the methods of packing it are thoroughly objective and easily determined whenever there may be any doubt as to classification. How different in this respect is the situation for the uses of electricity has already been shown, and attention has also been called to the fact that the railroad does business chiefly with dealers instead of with ultimate consumers. Use classification, notwithstanding the specious suggestion of its name, is not designed to help or to serve consumers but to get more revenue from them and it is, as such, a mere commercial device. It is not necessarily objectionable economically, if workable, and if applied in a way to extend business rather than to tax most effectively what comes, but in electrical rate-making it is evidently a poor instrument of the former purpose and is objectionable on the general ground of not being impersonal or not readily accepted as such by consumers.[18]

(New York Public Service Commission for the First District, Annual Report, 1912, vol. III, Table XIII, XXIV, VIII and XIX.) But the electrical companies are little interested in this field for the extension of use, because such consumption does not appeal to the imagination—possibly often also because there is a tacit division of the field with associated gas companies.

[18] The viewpoint that general economic results rather than formal classification of uses properly controls is well worked out in an English opinion (Justice Astbury, Hackney Municipal Council's rate decision): There is one class of energy and no dissimilarity of circumstances in the manner of its distribution, but there is dissimilarity "in the circumstances of the customer in so far as they react on the supply that he takes and in the time,

The policy of adjusting rates with reference to performing the maximum amount of service—service meaning benefit to society, not the extension of one agency at the expense of another that is equally effective economically—is of a different nature from the various applications of the value-of-service theory just mentioned. It is in no way antagonistic to cost analysis, and is the best business policy for the long run. Differentiation based upon broad economic grounds is not to be identified with manifestations of the commercial instinct that strives to get all the business and to take from each customer all that the traffic will bear.

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diversity, and quantity of consumption. In other words, the purposes to which the customer puts his energy which he purchases, whether for lighting, power, or heating, is *per se* irrelevant. It is in the quantum of and the circumstances in which he takes his supply of the one product" that one should look for controlling considerations. Light, heat, and power classifications have reference to load factor, diversity factor, and quantity. 11 Rate Research 366-7.

## CHAPTER V

## LOAD-FACTOR RATES

Practical importance of the load factor. Illustration by the results of three analyses of operating expenses into consumer, output, and demand costs.

*The practical significance of the load factor.* Peak demand and load variation. Importance of diversity. Definition of "diversity factor." Individual diversity and diversity ratio. Individual load factor still of technological importance. High load-factor business. The Hopkinson rate easily adapted to take account of diversity.

*Seasonal variation as a load-factor consideration.* The monthly basis ordinarily used for demand charges not theoretically sound. The bill period significant also for quantity discounts. Illustration by New York City rates. The filling of the summer valley, raising the hourly average for the year, should be recognized in rate schedules. Further meteorological considerations. Daylight saving.

*Load-factor considerations in relation to the small consumer.* Economically impracticable to base rates for small consumers on actual load determination. Inadequacy of methods of estimation commonly used with the Wright rate. The minimum rating often too high. Inadequacy of the recognition of diversity by way of averages. Diversity as a positive reason for simplification of rates. Residence lighting especially entitled to consideration on this score. Power no permanent advantage in this respect. A low kilowatt-hour charge encourages diversification. Long hours' use less important. The principal business of electrical companies is now power supply. Denser use by small consumers too little favored. Simple load-factor methods.

*Load-factor rates for large consumers.* The metering of load variation is entirely practicable for large consumers. Wholesale concessions should be conditioned by load-factor and diversity ratios; and may, when so conditioned, be large. Hopkinson the appropriate rate type. Public interest in elimination of arbitrariness. Load-factor rates based upon measurement should be available to consumers of intermediate size upon reimbursement for metering. Load-factor discounts should not be mixed with quantity discounts.

*The differential character of load-factor rates.* Fixed costs not simply allocable per unit of product, not separable. Kilowatt cost does not vary directly with the consumer's maximum demand. Even the simultaneous demand not sufficient. Off-peak use of plant not costless. Constructive differentiation of rates suggested. Not necessarily arbitrary. Bearing of the scale of generators. The lumping of small consumers. Problem of reserve capacity.

In this chapter it is purposed to set forth the true economic significance of the load factor, and then to show how it serves rather as a guide in differentiation than as a cost foundation of rates.

How important the load factor is may readily be shown. A central station may have an annual load factor as low as 15 per

cent. The load factor of a company with diversified business in a large American city will be 30 per cent or better. Operating costs may, for the purpose of the present illustration, be assumed to be unaffected by the load-factor situation. Fixed charges, on the other hand, remain substantially the same whether the load factor is 15 per cent or 30 per cent. If fixed charges account for two-thirds of the costs in the case of the less well situated company, it is evident that one with the same volume of ouptut, but with a 30 per cent instead of a 15 per cent load factor will be able to charge one-third less for the energy supplied. It is obvious that a rate schedule designed to favor those classes of consumers that contribute to a favorable load factor will tend greatly to reduce costs and thus justify a considerable amount of differentiation between, let us say, long-hour users and short-hour users.[1] Or the rate schedule may apply the two-charge method and recover operating expenses on the basis of kilowatt hours consumed and fixed charges on the basis of kilowatts of maximum demand.

Data of load-factor economy, if they are not merely hypothetical, suppose the detailed classification of operating expenses and fixed charges according to the principles governing their variation. In a leading case the Wisconsin Commission has divided electrical operating expenses in the following ratios: Consumer cost, 13 per cent; output, 67; and demand, 20. Including taxes, fixed charges, etc., the ratios become 17, 62 and 21 per cent respectively.[2] The results suggest too heavy a loading upon the kilowatt-hour element, of course as regards fixed charges, and also as regards operating expenses. For other revenue deductions, depreciation, income deductions and profits, the Commission assigned 20 per cent to consumer cost, 56 to output and 24 to demand.

A composite analysis made by an officer of a large electrical company[3] gives the following results:

[1] Cf. for one way of putting it, Wallis, Forsee System of Charging: "Capacity is the station's most valuable stock in trade and current the least valuable." 1901 N. E. L. A. proceedings, page 34.

[2] Madison Gas & Electric case, decided March 8, 1910, 4 W. R. C. R. 501, 668.

[3] S. E. Doane, High Efficiency Lamps, 1910, N. E. L. A. Convention proceedings, vol. 1, pp. 152-170.

| | Per cent distributions between | | | Per cent of total |
|---|---|---|---|---|
| | Output | Demand | Consumer | |
| General expense | .... | 76.9 | 23.1 | 12.0 |
| Distributing expense | 47.0 | 28.9 | 24.1 | 14.4 |
| Generating expense | 72.0 | 28.0 | .... | 23.9 |
| Taxes and insurance | .... | 84.0 | 16.0 | 7.8 |
| Depreciation | .... | 81.8 | 18.2 | 9.8 |
| Interest and dividends | 19.7 | 63.7 | 16.6 | 32.1 |
| Total | 30.3 | 55.1 | 14.6 | 100.0 |

With the aid of the last column combined distributive figures for the first three items may be obtained. These are: Consumer 12.4; output, 47.7; demand, 39.9.

A detailed study of the operating expenses[4] of a large company by the present writer—carried out, however, without access to sufficiently detailed information as to the operating conditions and accounts of the company—gave the following results: Variable per consumer or per meter, 12.6 per cent; variable per kilowatt hour, 48.4; variable per kilowatt of demand (subject to qualification with regard to diversity),[5] 30.6; fixed (not variable with ordinary changes in volume of business), 8.4 per cent.[6]

It will be noted that, in the last-mentioned analysis, a considerable portion of operating expenses is treated as fixed in amount—of course only within the limits of ordinary changes in operating conditions such as a commission would need to take into consideration in dealing with a rate case. Estimated provision for depreciation is not included in operating expenses as thus analyzed. Its inclusion would considerably increase the last two ratios and correspondingly decrease the others, especially the second. The per unit costs obtained, which are also of some illustrative interest, were: Per meter per year, $5.75; per kilowatt hour, $.0114; per kilowatt of demand upon the central station per year, $11.78; the "fixed" element not being applicable to any rate unit. Further

[4] As of the year 1911.

[5] Refers to the station maximum and the individual consumer's share in it, not to individual maximum demand.

[6] This fourth element in cost variation appears in W. J. Greene's enumeration in his important article in the Electrical World (Vol. XXVII, p. 222, Feb. 29, 1896), A Method of Calculating the Cost of Furnishing Electric Current and a Way of Selling It. The writer was not acquainted with this article at the time of making the analysis referred to. Greene also lists separately the number of consumers and the size of meters, without, however, suggesting that they be the basis of rate elements as does Doherty (cf. footnote on p. 70, above). Greene was, in fact, the protagonist especially of the minimum charge.

allowance for depreciation, income deductions, etc. would of course affect chiefly demand and fixed costs. These two may, for most rate-making purposes, be combined.

All the figures in this section are offered as having illustrative, not probative value. It is worthy of note, however, that there is very close agreement as to the share of consumer cost in the total and considerable variation in the apportionment between output and demand cost. This difference suggests that the apportionment in question is not so definitely a matter of cost accounting as is commonly assumed.

### The Practical Significance of the Load Factor

The load upon a station is the rate of energy supply (best expressed in kilowatts) made necessary by the demands upon the station at the time specified. A succession of values thus determined and plotted for any period of time gives the load curve of the station. The peak in such a curve comes where the rate of energy supply is at or close to a maximum. There is a peak for each day, perhaps also subordinate peaks, and a seasonal (annual) peak in winter. The load factor is the ratio to such a peak—for example, the maximum peak for the year—of the average rate of supply during the specified period of time that includes the maximum in question. If the necessary capacity of energy-supplying or consuming equipment is determined at the maximum, the load-factor ratio expresses the ratio of actual use in a period of time to the greatest possible use in that time.

The load factor relates primarily to an electric generating or distributing system or part of such system. In the case of a company with several generating stations, it is the company or system load factor that is particularly significant. An individual consumer, on the other hand, may equally well have his load factor computed, if only the necessary data are at hand: That is, in particular, if his maximum is measured. Every group or class of consumers likewise has a load factor, though it is seldom practicable to measure it.

It is easy, at this point, to let one's reasoning go astray by identifying the interest of the company in building up a good load for itself with a policy of favoring consumers with good individual

load factors. The acquisition of a new consumer with an individual load factor better than that of the company must, it is true, tend to raise the company's load factor. But it is also possible that an individual consumer with a bad load factor may better the load curve of the company to an even greater degree than the consumer with an especially good individual load factor. It is only necessary that all his consumption come at off-peak times. In other word, "diversity," in the somewhat technical sense of the word, is just as important as long hours of use. Therefore, as a matter of strict theory, a straight demand charge should relate to kilowatts at the time of the station peak.

Though this fact is not yet accorded its proper place in rate theory, and still less in rate practice, the term "diversity factor" is officially defined by the American Institute of Electrical Engineers[7] and familiar to all students of electrical rates. Disregarding certain refinements of the formal definition that have no direct relation to present questions, we may describe the diversity factor as the ratio of the sum of the maxima of a group of consumers to the maximum demand of the group in question when the individual requirements are combined. This ratio is greater than unity, often much greater. A figure representative of the diversity factor for residence lighting from consumers to power station is 5.5 or 550 per cent. Of course the diversity factor applies between groups as well as between individuals. It is of great technological importance in relation to the planning of a distribution system as well as of economic interest in relation to load factors and rates[8]

[7] See p. 13, above.

[8] The following is from Gear and Williams, Electric Central-station Distribution Systems, p. 369.

DIVERSITY FACTORS

| | Residence light | Commercial light | General power | Large users |
|---|---|---|---|---|
| Between consumers | 3.35 | 1.46 | 1.44 | ... |
| " transformers | 1.3 | 1.3 | 1.35 | 1.15 |
| " feeders | 1.15 | 1.15 | 1.15 | 1.15 |
| " substations | 1.1 | 1.1 | 1.1 | 1.1 |
| Consumer to transformer | 3.35 | 1.46 | 1.44 | ... |
| " " feeder | 4.36 | 1.90 | 1.95 | 1.15 |
| " " substation | 5.02 | 2.19 | 2.24 | 1.32 |
| " " generator | 5.52 | 2.41 | 2.46 | 1.45 |

It should be noted that in the "large-user" class diversity in a broad sense is important as between various applications by the same consumer.

According to the definition we cannot speak of the diversity factor of an individual, since the concept supposes a group of consumers. But, with reference to the relation of the period and amount of the individual's consumption to the system (or other group) peak, we may speak of his characteristic diversity. The individual's diversity may be conveniently defined numerically as the ratio of his total consumption per day (or per year) to his rate of consumption or his "demand" at the time of the station peak. To make this ratio conveniently comparable with the load factor the individual's demand at the station peak hour should be the unity term of the ratio. This second quantity may appropriately be called the consumer's "simultaneous demand."[9] A consumer's requirement at the time of the station peak may be on the slope or even in the valley of his load curve. In strict logic the diversity ratio ought to be understood in place of the consumer's individual load factor in most theorizing about the relation of the load factor to rates, especially as regards writings published prior to the general recognition of the importance of diversity.

An alternative mode of expressing the relation of an individual's consumption to the central-station peak is the ratio of his maximum demand to his demand at the time of the station peak. It has been proposed that this be called the *individual* diversity factor.[10] But this conception attaches importance to an individual peak that is usually to be provided for under off-peak conditions—an operating problem, and a simple one except for the very largest consumers—while the diversity ratio is directly a measure of the individual's contribution towards raising the level of the valleys.

In one respect it is necessary to qualify the statement that the electrical company is interested in the individual consumer's diversity ratio rather than in his load factor. It is his load factor that determines the necessary capacity of his service connection and,

[9] "Simultaneous peak" is the not altogether appropriate term used by H. E. Eisenmenger in an article in the Electrical World, May 24, 1913, vol. 61, P. 1085, entitled The Theoretical Basis of the Multiple Rate System. This and other articles of the same writer are characterized by an interesting use of tri-dimensional diagrams. Cf. his contribution incorporated in the 1911 report of the Rate Research Committee, N. E. L. A. Convention proceeding, 1911, vol. 1, p. 291; also, Some Geometrical Aspects of the Three Charge Rate System in the Electrical Review and Western Electrician, 1911, vol. 58, pp. 280, 332, 384.

[10] H. B. Gear, "The Application of the Diversity Factor," in the technical volume, proceedings of the National Electric Light Association, 1915 Convention, p. 245; also at p. 358 of Gear and Williams, Electric Central-station Distributing Systems.

except as the broadening of group diversity affects the situation, of the other means of supplying him. But in proceeding from consumer to the central power house through services, circuits, transformers, cables, etc., the individual load factor rapidly loses its economic significance until, at the power station itself, only the consumer's simultaneous demand, not his maximum demand, determines necessary investment and kilowatt cost. Even for the joint service connection of an apartment house, which thus pertains to a fairly homogeneous group of consumers, the sum of the individual maximum demands of the tenants is several times the maximum demand on the service.

The diversity ratio as above defined is of no great practical interest in the case of small consumers, since its value cannot be determined except where a special type of meter with clock attachment is used, such that the consumer's load curve is registered for (say) every 5-minute interval. This is commercially practicable only for the large consumer. But a clear conception of the diversity ratio should help to clarify one's ideas as to the significance of load factors. It is possible that it should be substituted for the consumer's individual load factor, with certain qualifications, in computing the demand charge, where this is an element in the rate; but that is a matter for consideration in another connection.

Certain kinds of business are very important with reference to load-factor considerations. Such considerations are likely to be at the foundation of any use or occupational classification of consumers. Perhaps pumping against a head has the most desirable load characteristics. The use of electricity for the fixation of nitrogen, and presumably for some other branches of the chemical industry, can offer a 100 per cent load factor. But the requirement of continuous operation creates a difficulty. The possibility of intermittent pumping at times conformable to the needs of the electrical supply company amounts to offering a load factor (actually a diversity ratio) of much more than 100 per cent. Special contracts are appropriate under some such circumstances. A comprehensive statistical study of occupational load curves appears to be wanting, though it ought to be of great interest to electric companies.[11]

[11] The Report of Committee on High Load factor and Non-peak Business, National Electric Light Association, 37th Convention, 1914, Commercial Sessions volume, p. 199, does something within the limits suggested by its title. There is an excellent compilation by

Whether the individual user has a sharp peak or not, or whether he makes a brief or long-continued use of his ordinary demand, are questions of secondary importance if his *diversity* favors the company. When electricity is used almost exclusively for one or few purposes, say for the lighting of streets, places of business and homes, it may be practically correct to assume that the individual

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J. E. Mellett for a variety of lines of industry, with results shown by individual daily load curves, for consumption at Camp Gordon (Atlanta), in the Electrical World for April 6, 1918, page 721 ff. The conclusion is drawn that control of the load by the central station is a more important reason for low rates than a low load factor. In other words, it is implied that diversity ratios should be emphasized more than load factors, though diversity is not mentioned by name.

Still more interesting are the following data obtained from a paper by Mr. Samuel Insull, "Centralization of Power Supply" (In Public Utility Economics, Lectures before the West Side Y. M. C. A., New York, 1914), p. 107. (The article is also published in phamphlet form). The table is slightly modified for reproduction here, kilowatt hours and the diversity ratio being derived and added to the matter shown.

DATA FOR CERTAIN LARGE LIGHT AND POWER CUSTOMERS WITH PRINTING TAPE WATT-HOUR METERS—COMMONWEALTH EDISON CO. OF CHICAGO (APPROXIMATELY 1913)

| Number of customers | Kind of business | Annual income | | Quantity of energy supplied (1000's of kw. hrs.) | Demand | | Diversity | | Load factor (per cent) |
|---|---|---|---|---|---|---|---|---|---|
| | | Amount (dollars) | Per kw. hour (cents) | | Maximum | Simultaneous (5:00 P. M. Jan. 6) | Diff. between maximum and simultaneous demand | Diversity ratio (per cent) | |
| 7 | Department stores... | 250,700 | 1.72 | 14,580 | 5,280 | 4,400 | 880 | 37.8 | 31.8 |
| 17 | Garages.............. | 93,400 | 2.23 | 4,170 | 2,220 | 90 | 2,130 | 528.9 | 20.4 |
| 4 | Office buildings...... | 59,700 | 2.24 | 2,660 | 960 | 720 | 240 | 42.4 | 31.6 |
| 15 | Steel, iron and brass works. | 172,600 | 2.02 | 8,520 | 3,280 | 980 | 2,300 | 99.2 | 29.6 |
| 14 | Manufacturers ....... | 159,000 | 2.05 | 7,750 | 3,680 | 1,550 | 2,130 | 57.1 | 24.0 |
| 2 | Stock yards and packing. | 66,200 | 1.24 | 5,330 | 1,550 | 830 | 720 | 73.3 | 39.2 |
| 5 | Telephone exchange and offices. | 34,500 | 2.23 | 1,540 | 480 | 380 | 100 | 46.5 | 35.6 |
| 7 | Ice manufacturers.... | 114,300 | 1.07 | 10,680 | 2,170 | 20 | 2,150 | 6097.2 | 56.2 |
| 2 | Hotels............... | 27,400 | 1.67 | 1,640 | 340 | 260 | 80 | 72.0 | 55.0 |
| 3 | Brick yards and quarries. | 21,600 | 1.91 | 1,130 | 650 | .... | 650 | ∞ | 20.0 |
| 6 | Cement works and miscellaneous. | 293,900 | 0.77 | 38,078 | 6,030 | 540 | 5,490 | 805.0 | 72.0 |
| 82 | | 1,293,300 | 1.35 | 96,078 | 26,640 | 9,770 | 16,870 | 112.3 | 41.2 |

The general diversity factor is 2.7.

consumer's peak occurs at about the same time as the company's peak, and that longer hours' use will mean additional use at other than peak times; but when there is diversified use and, in particular, a heavy daylight load for various applications of power, the diversity of the individual consumer can no longer in justice be disregarded. Then it becomes important to pay attention to the relation of an individual's consumption to the system peak rather than to the shape of his individual curve. It is possible, for example, that in our largest cities the domestic lighting consumer has come pretty generally to take practically all his electricity at off-peak times, with reference, that is, to diurnal peaks. Such consumers may tend to reduce the station load factor wherever the daylight and twilight demand account for most of the consumption of electric energy. Diversity may, it is true, be taken into account in the method of determining assigned maxima—as also, of course, through the classification of consumers—but such a method is rather unreliable.

But it is self-evident that, if all consumers had individually high load factors, the company supplying them would inevitably have at least as good a load factor as they have, hence the load factor of the consumer may well be a basic fact for the rate schedule. The demand charge, however, should be modified with reference to diversity.

### Seasonal Variation as a Load-factor Consideration

With reference to the extent to which seasonal as well as diurnal variation of demand is to be recognized, the method of determining the demand is worthy of more attention than it ordinarily receives. The Wright rate on a monthly basis, supposing the peak is actually determined instead of being arbitrarily assigned by classification, disregards the seasonal variation.[12] The demand element in the total charge is, under such conditions, based upon a new maximum for every bill rendered. Hence, for the year, the demand upon which this element in the rate is based is in effect the

[12] Again it is necessary to remind the reader that this characteristic of the Wright rate as actually applied in this country is not countenanced by the ideas and practices of Mr. Wright himself. It appears that at Brighton he took as the consumer's maximum the average of monthly peaks for the six winter months. (See the 1896 article.) He also allowed a residence consumer who planned to give an evening entertainment to have the demand indicator switched out that evening for a nominal fee.

average of twelve monthly maxima, instead of being the largest of them and the one that, in theory, decides the kilowatt burden on the supply enterprise. Under these circumstances, with a given yearly maximum, the smaller the other monthly maxima, and presumably, therefore, the smaller the off-season consumption, the lower the aggregate demand charges for the year. This situation in effect means the exemption of the consumer from paying the cost that his seasonal, as distinguished from his diurnal, load-variation imposes. The Hopkinson rate for large consumers, on the other hand, is in practice likely to be put on a yearly basis, so that the annual (winter) peak affects the rate the year round. This properly asociates the demand charge with the necessitated fixed investment. The sharpness of a peak (resulting from diurnal variation) is of course an important factor also. But the relative importance of a yearly peak is a function of daily as well as seasonal variation. The demand element in a Hopkinson rate, which it may be assumed relates directly to the yearly peak, thus reflects the influence of both annual and diurnal variation of demand.

The bearing of the bill period upon the variation of the average rate per kilowatt hour is of interest, not only in relation to whether the maximum (if a factor in the rate) is determined for the month or for the year, but also in relation to whether quantity discounts according to kilowatt hours taken are granted on the basis of monthly or yearly consumption. If the discount depends upon monthly consumption, the greater the unevenness of the consumption, the lower the average rate. This effect, however, is not likely to be of great practical importance in terms of revenue involved.

With regard to the chief factor determining the variation during the year in the amount of energy consumed per month, that is, the duration of daylight, if the peak for domestic lighting is retarded from winter to summer by only an hour and a half, and for other lighting correspondingly, and if the average hours' use of the actual maximum is as small for lighting as is commonly stated, the range of variation on monthly bills during the year, even without assuming vacations or shut-downs, must be very considerable. In the latitude of New York the range of variation in the need of artificial light as determined by the time of the sun's setting on the longest and shortest days of the year is about three hours. If the time of lighting up residences ranges between 5:30

and 8:30 P. M., and if the time for extinguishing the lights is typically 10:30, then the quantity of energy required might be expected to show a seasonal variation from minimum to maximum, due to this cause alone, in the ratio of 2 to 5. Diversification, even with reference to the lighting function only, will of course considerably reduce this range of variation. But with reference to this factor of seasonal variation considered by itself, the range evidently nearly equals the average consumption per month. If the range in question happens to equal this average, and if the average happens to be in the neighborhood of a change from one monthly block rate to another, the consumer will get the benefit of the lower rate to the extent of about one-eighth of the energy, merely because of his seasonal irregularity, by reason of which he takes more than the average quantity in winter when the kilowatt demand on the company is especially heavy. Furthermore, since he is a lighting consumer, his additional consumption is likely to come at the peak time, that is, at the close of the winter afternoon. Yet practical rate-making pays little attention to this matter, doubtless because it is so convenient to close up the consumer's account finally for each bill period.[13] For large consumers, at any rate, this should not be done, even if only with reference to the educative value of a more scientific adjustment with regard to seasonal load-factor considerations.

To illustrate the point more in detail—it is not mathematically correct to reduce the annual to a monthly basis as is done for plotting purposes in order to compare the General and the Wholesale rates in Figure 5, presented at page 160, below. The difference between the two bases in favor of the General rate may be illustrated by an example. A consumer under this rate with an average consumption of 6250 kilowatt hours a month will, if his consumption is only 900 for the smallest and 11,600 for the largest month, pay less for these two months than he would if he took 6250 kilowatt hours in both months. The cost of 11,600 kilowatt hours in $536.25; of 6250, $308.88; and of 900, $72.00. The cost of the two months even consumption is therefore $617.75, and uneven, $608.25. The

[13] The quantity discounts under the New York Edison wholesale rates (minimum now 75,000 kilowatt hours a year) are, since 1911, on the yearly basis; those for retail consumers are on a monthly basis. Chicago rates for small consumers especially, like Wright rates in general, are on a monthly basis. In fact only in wholesale rates is any other basis common.

consumer thus gains $9.50 on account of a peculiarity of his consumption that is not favorable to the company. If all the 12,500 kilowatt hours is taken in one month, and none at all in the other, $33.75 more is added to the difference, making the total gain to the consumer from unevenness of consumption $43.25. But the illustration is an extreme one and doubtless the indeterminate or suspended character of the charge for a considerable period where it depends upon annual consumption far outweighs any advantage of the annual basis in the case of small and medium-sized consumers. Only fluctuations ranging across the blocks between 900 and 1900 kilowatt hours a month affect the amount of the final payment, hence neither the consumers that take always under 900 kilowatt hours a month nor the ones who take always over 1900 kilowatt hours are affected by this peculiarity.

This question as to the importance of seasonal variation in relation to the load factor involves a question as to the comparative economic significance of filling in the valleys of the load curve and of merely keeping for the most part off the peak. If adding to the peak definitely involves the requirement of a certain addition to generating or distributing capacity, that is the crux of the situation and of unique importance. If, however, the responsibility for the peak is divided and variable, and somewhat indefinite and an affair of averages, then raising the level of the valleys may be as much worthy of attention as keeping down the peak. Of course the filling of the valleys is not an affair of a brief interval of time. But if consumption is maintained at about a given level throughout the spring, summer, and autumn, such a long-continued, steady load (a plateau in the consumer's load curve) affects the general average by raising the level of the seasonal valley. The permanent disadvantage of lighting consumption lies here.

Irrigation rates, on the other hand, though available only in limited sections of the country, have a permanent advantage that is the complement of the disadvantage of the lighting load. But in at least one case the irrigation load has been so developed as to cause a summer peak.[14]

The importance of the peak is *relative* to the average—a fact duly expressed in the load-factor ratio. Consumption that affects

[14] Idaho Public Utilities Commission, June 2, 1920, *re* application of the Idaho Power Company to increase its irrigation rates. 17 Rate Research 212; P. U. R. 1920D 806.

favorably the average for the year—the first term of the ratio—has an importance that may not be indicated in its immediate relation to the winter maximum or to an average of diurnal winter peaks. So far as the character of the diurnal load curve of a lighting consumer is in question, if there is a constant demand from 5:30 to 10:30 P. M. on a winter day, the diurnal load factor is 5/24ths, or 21 per cent, which is not bad where no diversity of use is taken into consideration. But various species of lighting load, among which are those of offices and of stores that close at 5 or 6 P. M., rank less favorably on an annual as well as on a diurnal basis. Street lighting, on the other hand, supposing lights to be burned all night, is evidently about the best kind of purely lighting load. But street lighting, also, has the seasonal characteristics that result from the variation of the hours of darkness. On the other hand, the controlling importance of astronomical factors in determining "hours' use" for different classes of lighting in the various months should, on account of their simple and certain calculability, facilitate the right treatment of lighting consumption with reference to the load factor and obviate to a large extent the necessity of resorting to special measurement devices. Such calculations, it is true, cannot take account of darkness due to sudden storms. But commercial and manufacturing establishments increase their demand more readily under such circumstances than do homes.

Not only does the lighting demand suffer in quality by reason of unavoidable seasonal variation, but it is also a source of sudden peaks in the off-peak season. A sudden thunder storm and darkness on a summer afternoon may cause the general turning on of lights and the superposition of a lighting demand upon the regular power demand such as to cause a peak nearly as high as occurs in December. This involves a difficult operating problem, which seems to have been quite satisfactorily solved. Such meteorological conditions are as little amenable to control as the astronomical determinants of seasonal variation.

The seasonal variation of demand for summer resorts is opposite in character from the general seasonal variation of the lighting demand and is often dealt with by a flat rate, by a considerable service charge on an annual basis, or by a higher rate per kilowatt hour for summer than for year-round consumers.

The daylight-saving plan of setting back the clock in summer further reduces lighting consumption at the slack season while leaving it the same in winter. It is thus an unprofitable thing for the electrical companies. Therefore it is not surprising that they are not among the advocates of this policy. That they should actively oppose what is evidently—at least as regards their part in the issue—sound national economy and almost pure gain to the public would be a discredit to the electric supply industry.[15] In fact, because the daylight-saving plan tends to force the companies to pay attention to the problem of seasonal variation, which they have hitherto rather neglected, it might in the long run inure to their advantage.

### Load-factor Considerations in Relation to The Small Consumer

Whatever may be the theoretical soundness of the demand charge, its application in actual rate-making is conditioned by the practicability of determining the character of the individual's load curve. In the case of the small, and even of the medium-sized, consumer, to do this satisfactorily, that is, with due regard for the bearing of diversity on the kilowatt requirement, is not worth while. Its costliness outweighs any advantage to be obtained by the resulting possibility of a finer adjustment of rates. The strongest advocates of strict maximum-demand rates, and of maximum meters in support thereof, admit that the method is inapplicable to the residence consumer.

There is the alternative possibility, frequently resorted to, of estimating the consumer's maximum demand, such as is the case where his connected load or something likewise related indirectly to his actual maximum is employed. This method, as employed in Wright rates, has been discussed above and various objections to it set forth. It does not conform to cost; it is hybrid in form; and it presumably ignores diversity. It is not adequate as a method of collecting a demand charge. The latter, as has been shown, is properly not a mere matter of long hours' use. Difficulties with registering the consumers' demand in this broader conception are no

[15] R. S. Hale, in an article entitled Daylight Saving in Boston Residences (Electrical World, Jan. 17, 1920, page 170), gives figures indicating that the reduction in bills on account of daylight saving is rather small, being 3½ per cent on bills amounting to $100.00 per year.

sufficient reason why it should not mean something more than his individual maximum. As an element in an electrical rate, its proper amount should be unambiguously and fairly determined. Diversity is equally important with the individual maximum.[16]

An evidently unjust feature of the Wright type of rate as sometimes employed in this country consists in fixing an unduly high minimum rating for active connected load—such that even very long hours' use cannot give the small consumer any benefit of the lower-priced block. This practice may be accompanied by a minimum charge, in which case it in effect duplicates or extends such charge. At best it is a poor substitute for an initial or service charge of some sort. If the minimum rating thus fixed is 1½ kilowatts and if the first block of a Wright rate is 60 hours use per month, the consumption of 90 kilowatt hours a month is arbitrarily required before any consumer gets the benefit of longer hours' use. Under such circumstances the rate for small consumers would be more honestly stated if there were no mention of the Wright features available for consumers of larger size. Such a system discourages long hours' use on the part of small consumers.[17]

[16] The assumption that the benefit of diversity should go to the central station—which is implied wherever the individual consumer's load factor is considered a final determinant of the demand charge—has been made explicit in the rather extravagant statement of a writer quoted in 6 Rate Research 342, who says that the diversity factor "is the birthright of the central station, the fundamental basis of its existence, and its resultant value belongs to the central-station company."

This is as if a bank should attempt to arrogate to itself by some natural or divine "right" the whole benefit of the diversity of the demands made upon its deposits. In fact, it is satisfied to get merely what it needs or deserves as determined by competitive and other elements in the business situation. It is scarcely necessary to say that neither actual rate schedules nor the expressed opinions of central-station men quite conform to the dogma enunciated. For example, Mr. John W. Lieb, of the New York Edison Co., in a paper on the Commercial Aspects of Electric Lighting (in the Johns Hopkins Lectures on Illuminating Engineering, 1910, p. 945) says (on p. 993): "The fixed charges and the standby charges ought rather to be apportioned to each consumer in proportion to his maximum demand [evidently his "simultaneous demand"] *at the day* and *very hour* the maximum load of the year occurred at the station."

[17] A closely related question is dealt with in the 1917 report of the N. E. L. A. Rate Research Committee, namely the point of incidence of the "follow on" rate, in other words, the proper point at which to pass from the first to the second block under a Wright rate. It is suggested that the first number of hours' use required, when low, may have been selected as the point of most economical use of light in order thus to encourage the liberal use of power and miscellaneous appliances. But, says the committee, it is perhaps most common to select the point according to the reduction of earnings desired to be effected. Convention proceedings, General vol., pp. 179-80. This is an interesting example of the way in which not even commercial exigency, but what we may identify as arithmetical convenience, rather than the desire to effect an equitable and scientific adjustment of rates, often determines the actual rate.

The individual consumer's claim to consideration in respect to the character of his load curve ought, if possible, to be recognized in the rate he receives. Such recognition involves recognizing his diversity. This is commonly done by way of averages. The objection to allowing thus for the diversity of a class of consumers by way of a class rate is that good and bad are lumped, and the average rate arrived at gives no incentive to the consumer to better the conditions of his consumption with reference to the company's load factor, which betterment underlies the recognition of load factor and diversity factor in any form.[18] But in the case of the small consumer the direct recognition of load characteristics is doubtless impracticable.

Diversity has not only a negative bearing on the question of a demand charge—in restricting the significance of the individual load factor—but properly also a positive influence in favor of simplification of rate schedules. If diversification of business is great enough, irregularities of demand tend to cancel each other and the diversity may of itself result in a fairly even load curve for the company. But so long as, or wherever, lighting takes the major part of the energy, this situation is not yet developed. The fact that in most places it is yet to be developed justifies for the time being a specially low power rate. This element in the existing situation counts for as much as the long hours' use of the power demand. But, if the kilowatt-hour charge is put as low as possible for the small as well as the large user, there is no reason why a situation like that which has prevailed for some time on Manhattan Island should not develop generally. Here the power load outweighs the lighting load by a considerable amount, as is evidenced by the proportion—that of approximate equality—of the two classes of connected load.[19] In other large cities the proportion of industrial power is probably greater, hence the statement may be made general for large cities. And there is a pronounced tendency to further rapid growth of the power demand. Of course, the kilowatt hours supplied for power must be much greater in proportion to connected load, perhaps twice as great, as for lighting. Moreover,

[18] Cf. the discussion of the weakness of classification in this respect in Chapter IV, page 112, above.

[19] See Annual Report of New York Public Service Commission for the First District, 1912, vol. 111, p. 75. The railway load is not included in the comparison.

lighting sockets are frequently used for other purposes than lighting. Residence lighting in Manhattan is off the peak in winter and its peak is often in summer smaller than the daylight peak.[20] The winter peak in large population centers is not due to lighting for residence purposes but rather to the superposition of lighting for commercial purposes upon power uses, in which combination lighting is becoming the lesser constituent. It is important to note that residence lighting comes on only gradually and does not reach its height till the dinner hour, while commercial lighting comes on full at twilight. In the largest cities in midwinter the peak of lighting for commercial purposes is reached by five o'clock.

Even apart from the especially rapid rate of growth of motor and similar uses of electric energy the developments of the recent past and the immediate future mean an increasing relative importance of the uses of which power is representative. The substitution of low-wattage, high-efficiency lamps for the much less efficient carbon-filament type should involve at least a cutting in two of the amount of energy taken for a given lighting use. The importance of the latest type of low-wattage tungstens as a factor in the situation has already been discussed. For the larger sizes of lamps there is the still more efficient nitrogen-filled type.

Other aspects of the diminishing claims of power for special consideration in the form of a low class rate have been considered above in Chapter IV. Its only permanent advantage over lighting is in respect to seasonal variation. As regards diversity, the residence lighting consumer, and that is but another way of saying the small lighting consumer, is coming to have a stronger claim to favorable rates than the power consumer. The tendency to use lamps of much higher efficiency enhances the force of the argument for ignoring the possibly high individual load factor of the residence consumer.

Diversified use on the part of residence consumers ought to be encouraged by low kilowatt-hour rates. Even if this involves some consumption at peak hours, for cooking especially, the diversity ratio would probably not be unfavorably affected, especially since

[20] Significant developments in this direction in Baltimore are effectively presented in an article in the Electrical World for July 28, 1917, p. 148 ff., entitled the Disappearance of the Evening Peak, by W. N. Neibich. It appears that in 1916–17 a condition had been attained such that there was an overlapping of the power and lighting peaks only during a period of six weeks.

the economical use of electricity in this connection probably supposes a combination of electric heating with the fireless cooker principle of confining the heat, thus involving slight and long-continued or merely intermittent consumption in preparation for a meal some time ahead. Other domestic uses naturally come mainly off the peak. The adjustment of interior wiring and of the wattage of sockets to meet such requirements, so far as it has not already been done, appears to be comparatively inexpensive.

It should be noted that, where domestic appliances containing motor or heat elements are used, these, rather than lights, will usually make the peak. But no one would allege that such applications of electricity should be restricted by maximum-demand rates. However, the advantages of diversification of residence consumption relate rather more to density-factor than to load-factor considerations. The subject is therefore discussed in that connection.[21]

Hence the conclusion that number of hours' use is not of fundamental importance in the case of the small consumer. It is necessary to add, *unless* possibly with reference to the greater density of consumption implied. Density of consumption, however, does not relate to the load factor, being another matter and a subject dealt within the following chapter.

But rate-regulating bodies have as yet taken little notice of this situation by reason of which the Wright type of rate, which leaves no place for diversity, is becoming increasingly unjust to lighting consumers. The Wisconsin Commission has recognized the strict inapplicability, according to its own premises, of its type of rate schedule to a town where the power load happens to be four times the lighting load, but it treats this case as exceptional and not calling for a modification of rules.[22] It doubtless is exceptional at present, but if something like this situation is to become standard in the near future, the Wright type of rate should soon be done away with, at least as relates to lighting consumers, unless frankly put forward (and remodeled) as a density-factor rate.

The argument for a new policy towards small lighting consumers with regard to load-factor considerations is reenforced by United

[21] See page 174 ff.

[22] The Berlin case, 1914, 15 W. R. C. R. 134. It is assumed in the decision that the power business could not be obtained at a higher rate.

States Census figures. With the horsepower capacity of motors reduced to kilowatts by multiplying by 0.746, and incandescent lamps similarly reduced on the basis of 50 watts per lamp, arc lamps being put down as returned, figures showing the comparative growth of power and lighting loads are as follows:[23]

| | Lamps wired for service | | |
|---|---|---|---|
| Year | Arc—number | Incandescent and other—estimated kilowatts | Stationary motors served—kilowatts capacity |
| 1902 | 385,698 | 910,000 | 327,000 |
| 1907 | 562,795 | 2,094,000 | 1,230,000 |
| 1912 | 505,395 | 3,825,000 | 3,081,000 |
| 1917 | Not reported | Not reported | 6,875,000 |

It appears that electrical-supply companies generally are no longer predominantly lighting companies. Estimating the kilowatts required for incandescent lamps on the basis of equivalent tungstens, the quantity should be reduced by half or more. But, with a lower cost per candle hour, of course the consumer will take more light. If the average hours' use of motors is two or more times that of lamps, allowance for this and for the fact that tungstens had still in 1912 to displace carbons for many consumers means that power supply is at present of much more than equal importance with lighting supply for electrical companies generally. Municipal plants are included with private central stations in the above data.

In brief, since it is not only difficult or impossible to do justice to the load-factor quality of the small consumer and give him an incentive to develop his consumption in the way most favorable to the company, and since so far as he is primarily a lighting consumer giving such an incentive is becoming unimportant, it would seem best to let diversity take care of his relation to the company's load curve, so far as it will, and for the rest, so far as necessary, develop other business in a way to make up for the small consumer's shortcomings. Perhaps this policy can as yet be followed unreservedly only in the large cities. There, at least, the aggregate consumption of the small residence (chiefly lighting) consumers is so small a fraction of the total that its contribution to the peak, for this as well as for other reasons, does not call for much attention. Doubtless the business of small consumers is not yet

[23] U. S. Census, Central Electric Light and Power Stations, 1912, table on p. 20; 1917, p. 98.

developed as it should be and as it will be, though the large consumers also offer by no means an exhausted field for the development of electricity supply.

Intensification of use is just as important for small consumers as for large consumers. Indeed it is presumably more important to the electrical company, because it can be assumed that the rate for the additional energy supplied will be higher for the former than for the latter class. The profitableness of the result is not lessened by the possibility that many small consumers are now being carried at a loss. It is perhaps necessary to explain that *extension* of use—the taking on of new small consumers—is not in question. Intensification of use refers to the increase of consumption in proportion to maximum demand or connected load on the part of individuals or classes already supplied. It is not impossible that, under a proper rate policy, such as to encourage this development, the more general use of a greater variety of domestic appliances might in a comparatively short time double the residence use of electricity. An initial charge accompanied by a low kilowatt-hour rate would tend both to prevent undue extension of electric lighting among the smallest-sized consumers and at the same time to encourage more intensive use among those not daunted by the initial charge. Apartment house dwellers constitute the class that one would expect most readily to respond to such a system. The appliances might be sold by the electrical companies at cost, or the more expensive ones rented at low rates.[24]

It is possible to base the rate to residence consumers upon load-factor principles without employing either the Wright or the Hopkinson method and without becoming involved in any complicated metering problem. The lighting requirement for each month may be agreed upon, as based upon connected load and other data, and kilowatt hours consumed in excess of the agreed quantity in any month may be billed at a lower rate than the initial quantity. The essence of the method consists in making the high-priced, initial

[24] Doubtless the extent to which gas is used for cooking, and the high per capita consumption, in New York City, especially in Manhattan Borough, is considerably affected by the policy of the Consolidated Gas companies, which had about 300,000 ranges and cookers rented at the close of 1914 in the borough named, the population of the borough being about 2,300,000 and the number of consumers, 675,000. For the data upon which this estimate is based see pp. 182 and 176 of vol. III of the 1914 Annual Report of the 1st District New York Public Service Commission.

block much smaller in summer, so that consumption at that season is encouraged, while consumption during the winter and at the peak season for the extra lighting then required does not obtain so low a rate.[25] The seasonal element in the load factor as well as hours of use are thus directly dealt with.

There is also an excess-demand watt-hour meter which integrates energy at a rate equal to the use in excess of a predetermined load.[26] This tends to keep down the individual diurnal peak and also, of course, though less effectively, the annual peak. The use of this device is not uncommon in Europe, though apparently not established in the United States.

As to the proper dividing line between small consumers, where load-factor rates are out of the question, and those of medium and large size, a monthly bill five times the quantity corresponding to the minimum charge has been suggested as an appropriate point for the use of the demand charge, if not of demand meters, to begin. If the most usual initial block has a bearing on the question, that indicates 50 kilowatt hours a month. But if the question is one of determining, not merely the consumer's maximum, but the character of his load curve generally, this amount is doubtless not large enough. As regards the expense of determining load characteristics by meter, there are certain advantages in providing for an intermediate size-class, where load-curve determination is optional with the consumer, but with the resulting cost added to the presumably lower price that he obtains through exercising his option in favor of a load-factor rate.[27]

### Load-factor Rates for Large Consumers

With very large consumers the situation as regards a demand charge is different from what it is for small consumers. With the former it is entirely feasible to determine the maximum demand of each day and the course of the load curve. It is possible to base the rate for such consumers upon the maximum peak or upon the simultaneous demand or upon any other feature or combination of

[25] The British Board of Trade has recently changed its method of computing minimum charges, so that the charge is the price of 10 units in the summer quarter and 15 in winter instead of the same the year through. 18 Rate Research 60.

[26] 1914 N. E. L. A. Convention proceedings, Technical vol., 24-25.

[27] Cf. page 114, above, on optional rates.

features of the consumer's load curve in relation to that of the company. Meters that record the quantity consumed during brief intervals are not absolutely inexpensive, either to own or to operate, but relatively to the energy taken by the very large consumers, in connection with whose supply they would naturally be used, the expense is inappreciable. Though it is not possible to make a simple general statement as regards the practice of the companies in this respect in dealing with large consumers, enough of them offer load-factor metering as at least an option to justify the opinion that rules requiring such metering for large consumers are entirely practicable.

It is the view of the writer that any concession below a certain amount per kilowatt hour under a single-charge rate, or per kilowatt of demand under a two-charge rate, whether under a so-called wholesale rate or under any other rate, should be conditioned upon the possession of load characteristics distinctly favorable to the company. As to what load characteristics should be required, it is evident that the individual consumer's demand at the time of the station peak, rather than his individual maximum or his hours' use, is the critical thing. The consumer's diversity ratio, and perhaps in addition his individual load factor, should be higher than the system load factor, if he is to receive marked concessions.

If the characteristics of his demand are decidedly good in these respects, it is difficult to say just where the concession of a lower rate should stop, since it is quite possible for such consumers to make up to the company the cost of the bad load characteristics of other consumers, in which case the former might claim concessions directly at the expense of the latter. This element in the situation should be dealt with by a scale of demand charges varying with the diversity ratio, subject to adjustment according to the realized load factor of the company. But it may in certain cases be dealt with by negotiation and special adjustment of the consumer's demand, for example, through the changing of factory hours so as to close the working day before dusk, thus avoiding to some extent the overlapping of power with commercial lighting.[28]

[28] Cf. E. W. Lloyd in 1916 N. E. L. A. Convention proceedings, genl. vol., p. 9: "In certain lines of business the cost of energy is becoming so great a factor that these industries are compelled to consider an adjustment of the hours of labor in order that power may be purchased at prices they can afford to pay." An article on Seattle conditions, entitled Keeping the Power Load off the Peak (Electrical World, Dec. 1, 1917, page 1056),

Not only adequate metering, but the control and limitation of peaks, especially momentary peaks, appears to be entirely practicable as regards large consumers. The systematic use of such control would go far towards justifying very low industrial rates under such conditions. Off-peak and limited-peak rates have an important future in such applications.[29]

The "filling-in process" referred to can best be accomplished by adjustment of the time of demand and by applying off-peak rates. The character of the consuming industry is an important factor in the situation, but a limiting rather than a controlling condition. Ice-manufacture appears to be the most generally eligible.[30] It will be noted that this use relates directly to the cure of seasonal inequality. It is an available recourse in all large cities.[31]

It is true that, even though the diversity of a consumer is not explicitly recognized in a rate schedule, it may easily be taken into consideration in determining how the consumer's demand is to be computed, if that is fixed otherwise than by meter. But this method throws wide open the door to discrimination and is therefore to be condemned. As the variation of demand comes to be recorded instead of estimated, diversity will doubtless come to receive explicit recognition in rate schedules wherever the load factor is made an element in the rate.[32]

Difficulties in making metering adequate to the application of load-factor principles to rates have long been an obstacle in the way of their proper development, as appears in the discussion of the determination of maxima in Chapter II above. With this obstacle removed, the policy of the electrical companies as regards rates for

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states the problem thus: "The peak is caused by the overlapping of the lighting and industrial power loads on the electric-railway evening-rush hour demand"; and suggests earlier closing hours and in other cases the leaving of employees at half-hourly intervals, always with due regard to their effect on the included street railway load. It has been estimated that "staggered hours" would save 15,000 kilowatts of demand at Boston (Electrical World, Nov. 16, 1918, page 940).

[29] Compare as to the control of peaks on the electrified portions of the Chicago, Milwaukee & St. Paul Ry., F. C. Pratt in the Electrical World, Oct. 4, 1919, page 753.

[30] Compare Williams & Tweedy, Commercial Engineering, pages 75-76.

[31] It is stated that 65% of artificial ice in Chicago is made by central-station energy, which is 28.5 per cent of all ice used there, including natural. Electrical World, March, 1919, page 600.

[32] The rate schedules of Detroit, Michigan, and of Rochester, New York, contain features that attach importance explicitly to diversity, the former by way of time differentials for auxiliary and emergency service, the latter by way of qualification of the demand charge for recorded peaks with reference to their time of occurrence.

large consumers ought rapidly to take fairly definite and fairly uniform shape.

The appropriate load-factor rate for large consumers, as is abundantly indicated, is of the Hopkinson rather than the Wright type. The decisive consideration in favor of the former is clear in the light of the importance properly attaching to diversity. The Hopkinson type of rate lends itself to the substitution of the diversity-ratio for the individual consumer's load factor (his "simultaneous" demand for his maximum demand), and also to any desired combination of the two. Lighting for commercial purposes would, under such a system, be made to pay for its usual bad diversity ratio as well as for its bad load factor.

Load-factor considerations applied to determine the proper rate for large consumers should be administered partly with reference to giving such consumers their share in the lower costs, but more particularly, from the public viewpoint, with reference to safeguarding the company and the public against undue concessions to bargaining power. To give those with special bargaining power carefully all that is their due by means that are unambiguous, taking nothing for granted, is the only way to be sure that such consumers do not get more than is their due. But from this point of view the density-factor feature of rates, to be considered in another connection, is of at least equal importance with the demand charge. Load-factor rate elements should not be used to disguise quantity discounts, and *vice versa* the quantity discounts should not be made specious by arguing from an assumed but not determined load factor. It is true, for example, that the large consumer will in general have a somewhat better load factor than the small consumer, but the fact is irrelevant and the argument merely specious if the better load factor results from a degree of diversity of use in the case of the former only such as would be matched by the diversity factor of a number of small consumers, taken at random, having an aggregate consumption equal to that of the large consumer.

As to consumers intermediate in size, it may be desirable to encourage off-peak business by various methods not requiring the use of load-recording meters. An outright concession to power uses may sometimes be made, though it should not be large in amount and should not depend on volume of consumption. It may be ex-

pected ultimately to disappear. Other sorts of consumption that are easily ascertained to be off-peak are entitled to similar concessions.[23] Furthermore, without direct reference to size, a consumer who is willing to reimburse the company for the expense of the special metering should be allowed the benefit of load-factor discounts. In the case of the large wholesale consumers, on the other hand, the expense of such special metering should not be the occasion of a special charge, since it is incurred quite as much on behalf of the public as of the consumer.

In brief, load-factor discounts should be designed to make business grow in the right direction *qualitatively* as well as quantitatively. In order to do this honestly and effectively they should not be mixed with quantity discounts.

### The Differential Character of Load-factor Rates

The subject of load factors is discussed as a phase of the cost of electric supply. This is the correct viewpoint. The distinction between running or variable costs and fixed costs is of general validity and of the greatest significance. But this statement does not mean that the distinction can be accepted without qualification or as something in its nature absolute. The variable costs readily lend themselves to analysis and allocation per unit of product. The fixed costs, it is usually assumed by engineers, lend themselves to similar analysis, but the unit is the kilowatt of demand.

If it is entirely true that kilowatt fixed cost can be so separated, then load-factor rates are not differential. But engineers and others interested in the separation and apportionment of costs to obtain unit figures are seldom prepared to appreciate the limitations upon such analysis that are implied in the theory and practice of differentiation. And the same engineer that carries his hard and fast cost analysis to the extreme limit may, as the manager of an electrical company confronted with competition, carry the practice of differentiation to equal extremes.

The fact is that a figure of cost of fuel per kilowatt hour generated and a figure of cost of generating plant per kilowatt of generating

[23] A "limiter" may be used to prevent excess demand on the part of a small consumer. The Oregon Commission has approved a rate (for ice-making), allowing a 50 per cent discount on that portion of the consumer's demand not used between 4 and 8 P. M. during the four months Nov.–Feb. 10 Rate Research 101.

capacity have not the same relation to the charge per kilowatt hour and that per kilowatt of maximum demand, respectively. In a general way, the coal burned varies with the kilowatt hours produced, and even though this be true only in a general way, it is a firm foundation for rate-making. That the central-station capacity is a function of the maximum demand of consumers, or varies with the consumers' demand, is not true in anything remotely resembling the same sense. If it were true that generating capacity must increase in proportion to the aggregate consumers' demand (even though a decrease in such a demand could not be reflected by a decrease in capacity) the functional relation would hold sufficiently for the purpose of basing rate-making upon unit fixed cost. But the consumer's demand, as ordinarily defined by reference to his individual peak, has no necessary relation to the kilowatt burden he imposes on the central station. The significance of the diversity factor in this connection need only be mentioned, since it has already been fully discussed.

Even if one wished to define the consumer's demand as his kilowatt requirement at the time of the station peak—which engineers are not generally inclined to do—there are theoretical and practical objections to apportioning fixed-charge cost completely on this basis. In the first place, is it economically sound or just to charge for the use of the plant at the time of the peak load *all* the fixed-charge cost and let the use of it at other times go entirely free of such cost? Of course some of the fixed cost can be spread out by putting it into the kilowatt-hour charge, and this element in the rate should be given the burden (not the benefit) of the doubt. But to do this is to abandon a fundamental point in kilowatt cost analysis, and to distribute some of the fixed cost differentially merely according to considerations of policy. And if here, why not elsewhere? For example, why not make the off-peak users pay some of the fixed cost and thus reduce below "cost" the unit charge for peak use of plant?

If the company sticks to the cruder conception of the individual consumer's demand as his maximum peak, however, something will be charged for the off-peak use of the plant, but in a rather hit-or-miss fashion. And under such a system the consumer's fixed cost per unit changes from year to year, owing to the development of

diversity to which he presumably contributes nothing, which grows up also without any encouragement from the company in the form of rates adjusted to promote diversification and a better load factor.

Should the company maintain a passive or nearly passive attitude in the matter of its load factor? If costs for plant imposed by the consumer are so definite and inevitable as they are often made to appear, of course the company can do nothing except be sure of its compensation. But if it can reduce these costs per unit of output by a proper adjustment of its rates, in the long run giving to the consumer most of the benefit of such reduction, why should it be fettered by a kind of cost analysis that at best takes account of the past rather than of the future? In other words, is not a differential policy the only sound mode of applying load-factor considerations in rate-making? The company should strive to smooth out its peak by diversification of business and by load-factor rates planned with reference to accomplishing this.

The analogy with the railroad-rate situation should be helpful at this point. Differential rates are there due to the policy of favoring certain classes of freight that will be shipped in large volume, and their purpose is the more fully to utilize the railroad plant, or the fixed capital. The electrical plant's problem in relation to obtaining a better load is somewhat different in its nature, but the fundamental economics of the two cases are the same. And the result to be expected is the same in both cases, that is, differentiation. The economist will naturally not look with favor upon a short-sighted attempt to make the thing more palatable by calling it something else. What is needed, rather, is the training of differentiation into conformity with economic principles. Differentiation is not necessarily or naturally associated with arbitrariness, though it can scarcely be reduced to rules of thumb. It is hardly necessary to say that electrical company managers usually pay more attention in practice to "value of service" than to strict load-factor considerations.

The ordinary conception of the basis of the demand charge, according to which it is simply a question of the consumer's individual maximum, has the appearance of making it possible to follow the thread of causation to its source in the case of the fixed-charge element in cost as easily as for the most obviously separable element.

The falsity of this assumption has been dealt with. But even if it were true—or if we could deal with the consumer's demand in an equally absolute way by identifying it with his kilowatt requirement at the time of the station peak—the differential character of the demand charge would not thereby be exorcised. In the matter of power-plant economy, it makes a great deal of difference whether a central station must provide for a large demand or a small demand. The difference between a 2000-kilowatt generator and a 20,000-kilowatt generator, both of which sizes are well within the extreme limits of the range of capacity of generators actually in use in central stations, is an important one for unit costs of construction and operation. According to the rule cited above [34] the specified increase in size should involve an increase of at least 65 per cent in physical efficiency. This of itself would be an incentive for the electrical company to expand its business by means of differential rates that affect the charge per kilowatt as well as that per kilowatt hour. Such elasticity in rate-making is more than the germ of differentiation and it accords ill with the notion that the determination of the demand charge is a matter of arithmetic instead of a question of business policy.

It should be understood and must be admitted that a differential policy may choose to ignore in large degree, instead of emphasizing, variations in the load-factor element in cost. In other words, the supply company may prefer to deal simply with the average, or with the several average conditions of a few large classes. The lumping together of the long- and short-hauled passengers of street railways affords a familiar illustration of this sort of thing.[35] But in this case the density-factor rather than the load-factor justifies the policy, hence the analogy with electricity supply is not direct. Moreover, and more important, the electrical company is in position to deal actively with the load-factor situation, and use its rate schedule to favor off-peak consumption, instead of merely accepting such advantages of diversity as accidental developments confer upon it.

[34] Chapter I, p. 28.

[35] J. W. Lieb of the New York Edison Co. cites this analogy (1916 A. I. E. E. Proceedings, p. 76). The differential character of street-railway rates is affirmed by the present writer in an article in the Quarterly Journal of Economics for August, 1911 (vol. XXV, p. 623).

The problem of meeting the maximum demand is not unmixed with the cognate problem of proper reserves of capacity for dealing with emergency demands and growth. It is obvious that insurance against the unexpected is a matter of providing a small per cent above the necessary maximum capacity—for this purpose including in the reckoning some overload capacity as available. The capacity reserve for growth is rather to be determined by the balancing of investment and operating economy in large units against the fixed cost of carrying an added investment for several years without direct return. The cost-accounting treatment of the first or insurance aspect of the problem of reserve capacity is not difficult. The capacity *necessary* to meet maximum demand, including the necessary capacity reserve (except so far as unexpected developments can be taken care of through overloading), is to be counted as cost. The excess capacity providing for growth, on the other hand, is not properly chargeable to *current* costs, that is, it pertains to some future year. As unused provision for growth it ought not to influence rates directly. In electricity supply there is much less need of anticipating future requirements by present physical provision than in the case of water supply.

The fact that load-factor theories deal with the fixed-charge element in cost in itself constitutes a presumption that a load-factor adjustment is differential in character, since it is almost obvious that the commercial tendency with regard to such costs is universally differential. An examination of the load-factor theory and of its application to actual rates serves to show that we have here, not a piece of ordinary cost accounting, but a peculiarly interesting and important species of differentiation.

## CHAPTER VI

### WHOLESALE RATES AND QUANTITY DISCOUNTS

Wholesale rates are presumably differential.

*Quantity discounts.* The difference between wholesale and retail prices not merely a question of quantity. Continuous character of electricity supply—no true whole-sale. "Quantity discounts" not a matter of form. Need of segregating initial or consumer cost, which is inappreciable above 200 kilowatt hours a month. Collection of such cost from adjacent size classes. Actual range of pure quantity discounts may be two-thirds or more. Such discounts properly apply to the kilowatt-hour element but may affect others. Power for transportation companies a special case. Large pure quantity discounts specious rather than sound. Intensiveness of use and density of consumption not the same as large quantity. Load-factor and density-factor considerations should be dealt with explicitly. Large power rates have been less regulated than others.

*The competition of isolated plants.* Bargaining power the foundation of undue concessions. Comparative advantages of the private plant. Aggregate isolated plant capacity probably as great as that of central stations. "Merchandizing" contracts for operators of tenement and loft buildings. Concession to the landlord as regards the wholesale minimum. Possibly other means of dissimulating concessions to those with special bargaining power. Bearing of the presence of isolated plants upon density-factor economy and upon the cost of transmission and distribution. A case where distribution is not a general or joint cost. Concentration as a means of wartime economy.

*The opportunity for diversification and intensification of use among small consumers.* Tendency to lump all small consumers under a general rate. The social importance of morselized power supply. Electricity in the household. Gas as a competitor. Motor uses more economical than heat uses of electricity. Even the urban lighting field not fully occupied. Importance of density and of rates adapted to promote it. Domestic uses entitled to more recognition.

*How volume of consumption may best be recognized.* Wholesale rates less a matter of course and more a matter of differentiation than is commonly supposed. True cost analysis leaves a zone of differentiation. The requirement of generalizability. Electricity supply not in itself of such a nature as to justify large qauntity discounts. Density, on the other hand, highly important. Mere quantity discounts not in accord with this idea. Isolated plants inimical to density. But the rate cannot be fixed merely with reference to "getting" the isolated plant. Possibility of co-operation with the latter. Desirability of making the density factor explicit in rates, perhaps as a discount for quantity consumed per foot of block front. Density not a matter of size. Distance from the station a different matter. Density factor discounts should be combined with load-factor discounts. High tension rates another matter. Public interest in putting wholesale electrical rates upon a sound basis.

In considering the subject of low rates for large quantities, or low rates to large consumers as such, it is again necessary to look

for differentiation. By differentiation, as has already been indicated, is meant the distribution of the burden of fixed charges according to some other rule than that of arithmetical uniformity. Wholesale rates and quantity discounts are not ordinarily thought of as differential in their nature. But it is a well known fact that differentiation carried to the extent of abuse and injustice has usually come about through immoderate concessions to large consumers due to their special bargaining power. Railroad rebates constitute an important example of this sort of thing. In the case of public-service corporations generally, wholesale rates may be presumed to be as much differential in spirit and purpose as are class rates. Hence the importance of inquiring into the basis and the legitimate degree of this sort of differentiation in connection with electricity supply.

### Quantity Discounts

The validity of a difference between wholesale and retail prices is universally recognized. Indeed the ordinary mercantile conception—which influences and in fact dominates economic thought much beyond the circle of the trading classes—is commonly allowed too much scope. The situation may be quite different from that supposed by such notions, if what is sold is not wares but the services of fixed capital, and if profits are no longer principally dependent upon the rapid turnover of circulating capital.

Where to draw the line between wholesale and retail is often a difficult question. Sometimes the lower price does not depend directly on quantity but comes by way of concessions "to the trade." Sometimes there is a fairly well marked objective distinction, as in the case of railroad freight shipped in car-load lots.[1] High-tension or primary power is similarly different from the low-tension electric energy in the supply of which the ordinary distinction between wholesale and retail rates applies.

[1] In a recent opinion of the Interstate Commerce Commission, in the Private-wire case, dated August 3, 1918, its position on the subject of straight wholesale rates, which is supported by preceding decisions in railroad cases, is explained as follows: "We have frequently stated that the so-called wholesale theory has no proper place in the rates of common carriers." 50 I. C. C., 757–8. This statement is followed by citations and quotations from previous opinions, among them: "Any discrimination . . . . in rates based upon the idea that one class of persons makes many shipments while the other makes but few is unjust and unreasonable." These principles are presumably applicable to other public-service corporations, as well as to common carriers.

In the case of electricity supply, the energy is furnished as a continuous, not a discrete, quantity. Here, if a distinction is made between wholesale and retail rates, the line must be drawn entirely on the basis of some arbitrary quantity. Classification will not help much, as has been shown in previous chapters. An objective electrical counterpart to the "commodity rate" practice of the railroads cannot be devised. Moreover, there is no distinction between large and small packages; and nothing of the nature of bulk delivery. It is not without significance that etymologically speaking there is no such thing as "wholesale" electric supply.[2] The original idea was evidently, for example, that of selling cloth by the piece instead of by the yard, a specified number of yards being cut off in the latter case as wanted. But there is no such a whole-piece price for electricity, the supply being potentially continuous. The wholesale-retail dichotomy can, as such, have little significance, since the lower unit costs resulting from a large volume of sales are in this case an effect that will be felt gradually and continuously in proportion to the scale of total sales, not at some definite point where the distinction between retail and wholesale is made. Hence the consumer is entitled to a graduated scale of reductions or discounts conforming substantially to the continuous variation of unit cost. If there is to be a so-called wholesale rate as distinguished from retail rates, the two should graduate into each other and both should exhibit variations within themselves on the basis of quantity taken.

Hence in the electric supply industry the fixing of a low wholesale rate is best effected through a succession of discounts for quantity taken. The difference between the step method and the block method has already been described. That the block method

[2] The reaction of the 1917 Rate Research Committee on this matter of terminology—it seems to be no more than a matter of terms in this case—is indicated by the following: "Objections have been raised to the use of the term 'wholesale rates' to designate rates for business bringing more than a stated minimum of income, or having a demand above a stated number of kilowatts. It is pointed out that the word wholesale suggests retail, and that the implied description as 'retail' of all services which do not qualify for the wholesale rate, may cause offense. Further, it is pointed out that the word wholesale carries with it the idea of wholesale purchasing and retail vending; it may be held to imply service purchased wholesale for the purpose of retailing to tenants or to neighbors.

"Our immediate comment is that local use and custom, or definition in the schedules of the purposes for which 'wholesale' service is offered, may prevent misunderstanding or offense, but that other available terms as 'large light and power rates,' 'industrial' rates,' 'bulk' sales, and 'high tension rates' are not subject to the recited criticisms." 1917 N. E. L. A. Convention proceedings, General volume, pages 177–78.

relates to something more fundamental than mere details of schedule-making technique has also been made evident.

It is perhaps necessary to say that the "quantity discounts" under discussion in this chapter are not to be understood merely formally as referring to the graduated scale commonly appearing in rate schedules under this name. These (as has been shown above in a footnote on page 48) constitute merely one way of formulating and expressing a step rate. In this chapter the reference is to any method of reducing the average rate as the quantity of energy taken increases. Quantity discounts can be effected by the block as well as by the step method, and indeed, since the former is in accord with the better and the prevailing practice, the block method will ordinarily be assumed to be the one to be considered. Moreover, quantity discounts that are more or less palliated or concealed, perhaps as prompt-payment discounts—on their face a curious reflection on the credit of large consumers—or as concessions granted in consideration of long-term contracts, or in return for large guaranteed minimum payments, or by way of graduation of the demand charge, are still economically significant merely as quantity discounts.

There remain to be considered two questions, one as to the proper range of variation between the small consumer and the largest one—involved in the distinction between differentiation and discrimination—and another as to whether the mode of making concessions purely on the basis of quantity consumed can properly be carried as far in electricity supply as in other industries.

But, before considering the range of the quantity discount proper, it is well to segregate the influence upon the initial rate of the initial costs of serving a particular consumer. This element in cost, that is, "consumer cost," so-called, is not peculiar to electricity supply, but is involved to a greater or less extent in any attempt to compare wholesale and retail prices. Consumer cost naturally varies considerably as conditions vary from city to city. We shall here use 50 cents per meter per month as merely a convenient round number that is approximately what the consumer charge for the small consumer ought to be.[3] This may in some cases be

[3] Cf. page 90 ff., above. The reference is to conditions not adjusted to the effects of the war.

rather low, but there are good reasons why the separate consumer charge should be as small or as closely calculated as is practicable.

For the purpose of determining the range of the quantity discount proper, after allowing for consumer cost, it is convenient to reduce the latter to terms of kilowatt hours. Upon the basis of 50 cents a month it is easy to compute its importance in relation to quantity discounts. Reduced to cents per kilowatt hour for various size classes of consumers the charge varies as follows:

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| For the consumer taking | | | | 10 | kilowatt | hours | per | month | 5c | per | kw. hr. |
| " | " | " | " | 50 | " | " | " | " | 1c | " | " " |
| " | " | " | " | 250 | " | " | " | " | 0.2c | " | " " |
| " | " | " | " | 1000 | " | " | " | " | 0.05c | " | " " |

and so on for intermediate and further points, the computation being a matter of the simplest arthmetic. At 200 kilowatt hours this element in cost accounts for a quarter of a cent per kw. hr. At 1000 kilowatt hours it is of very little importance as an element in the rate. It is evident that if we compare the rate at 200 kilowatt hours with that for the largest quantities provided for in the rate schedule, the range of variation between these two points should be affected by consumer cost only negligibly. The conclusions to be drawn from such a computation as this would remain substantially the same if the consumer charge were multiplied by 2. It is easy to test the importance of this or any other fixed amount in relation to the variation of the kilowatt-hour rate.

A qualification is necessary, however, with reference to the possibility of the rate somewhat beyond the range of the smallest consumers being kept high enough to compensate the electrical company for not collecting full consumer cost from the very smallest class. This practice, where pursued with moderation, is defensible on the ground that, in price-making—though not in dealing with most other demands for justice—it is often sufficient that justice be done *in the average* rather than in each individual instance, though the averaging should not be too rough and ready but should, on the contrary, treat like cases alike so far as practicable. But such a method of compensating for initial costs properly applied should scarcely affect the rate above 100 kilowatt hours a month.

Where the demand charge does not count directly, the range of the quantity discount can be easily determined. It happens that the rates of one of the most important electrical companies in the

country, the New York Edison, are, since 1911,[4] entirely on a quantity basis so far as relates to low-tension consumers, the exceptional consumers being few in number and of very special character, the use of high-tension alternating current involving the installation and operation of expensive apparatus for what is in effect the further manufacture of the energy on the consumer's premises. For such high-tension consumers the company has Hopkinson rates.

The wholesale rate of the company referred to is a strictly "block" rate, hence only the mathematical limit of the average rate, that is, the rate for the last block, can be stated definitely without reference to specific volume of consumption. The lowest rate is 2 cents and is for the block "over 1,100,000 kilowatt hours a year." The charge in excess of 2 cents for the preceding blocks adds .875 cents per kilowatt hour to the 2 cents at the 1,100,000 kilowatt-hour point, making the average rate there 2.875 cents. For a consumer taking 2,200,000 kilowatt hours a year the average rate would therefore be 2.4375 cents. Previous to May 1, 1915, the lowest low-tension rate to the largest consumers (from 833,333 kilowatt hours a year up) was 3 cents straight, the straight rate having been obtained by the interjection of a free block. Under the old schedule the range of variation of the rate was equal to the difference between 9½ (the maximum less half a cent for lamps) and 3, or 6½ cents. In commercial terms, this amounts to a 68 per cent discount. Under the present schedule it is difficult to say what is the practically significant extreme range. At 833,333 kilowatt hours the present average rate is 2.995 cents. The maximum was reduced to 8 cents on May 1, 1915, and further to 7½ on Jan. 1, 1917, then to 7 on July 1, 1917. Adjustments in the early blocks confine the effect of the 1917 reductions to the initial portion of the average-rate curve. The ratio of the maximum rate to the average rate at 833,333 kilowatt hours per year is evidently less than the ratio of 9½ to 3. The figure that is in the same ratio to 8 that 3 is to 9½ is 2.526. Only consumers of nearly 2,000,000 kilowatt hours a year get such an average rate. The initial block at 8, 7½ or 7 cents ex-

[4] Just prior to 1911 the rate to the so-called "intermediate wholesale class" involved the "hours' use" basis, but the wholesale rate itself was already purely a matter of quantity of energy taken. In its report to stockholders in January, 1912, the Consolidated Gas Company, which controls the New York Edison, characterizes the rate schedule adopted by the latter in 1911 as "designed . . . . to insure to each customer a rate commensurate with the volume of electric energy be consumed."

tends to 900 kilowatt hours a month, and the previous initial block extended to 250. Consumer cost is doubtless more than taken care of before either of these points is reached. Thus, it is not necessary to make any appreciable allowance for this element. The pure quantity discount is still about two-thirds of the price to small consumers. This is probably less than the quantity discounts contained in the rates of other companies, but it is seldom possible definitely to determine their range. The New York Edison has not gone farthest in this direction, but it appears, in its schedule, to pursue the ends in question with a directness and simplicity of which the example is not without influence upon the industry generally.

The character of the New York Edison rates—though they cannot be considered representative or prevailing practices—is of general interest because of the importance of the example. They also lend themselves neatly to graphic representation. Figure 5 is presented to show a thorough-going system of quantity discounts. The diagram is comprehensive for all low-tension rates (as of 1915) of the New York Edison and United Electric companies, which supply practically all Manhattan and The Bronx. The classification is of the simplest. All graduation is on a purely quantity basis and by means of blocks, not steps. But in order that the quantity discounts be applicable, the energy must be supplied to the same owner or leaseholder, and to the same building or to buildings not over 100 feet apart. A system of chain stores, for example, cannot, as such, get the benefit of the discounts.[5] Figure 5 shows both the rate blocks and the variation of average rates. An explanation of the necessary inexactness of the means adopted for reducing the wholesale rate, which is on an annual basis, to the monthly basis of the retail rates, is given on page 134, above. The construction of Figure 5 need not be further explained.[6] It will be noted that, within the range of the curves, which reach the very largest class of consumers, the average rate drops for the wholesale class to 33

[5] A rider of the Commonwealth Edison Company of Chicago, recently abolished by the Illinois Commission, granted discounts where more than one premise was covered by one contract, of 5 per cent for two and one per cent more for each addition, but with a limit of 20 per cent and of four cents per kilowatt hour. 13 Rate Research 38, 40. P. U. R. 1918B 732.

[6] A detailed description and interpretation, together with the diagram, is contained in the Annual Report of the New York First District Public Service Commission for 1915, vol. III, pages 119ff. The rates have been slightly modified, since the date of the diagram, not, however, in a way to involve any change in principle.

FIGURE 5

# ACTUAL ELECTRICAL RATE CURVES

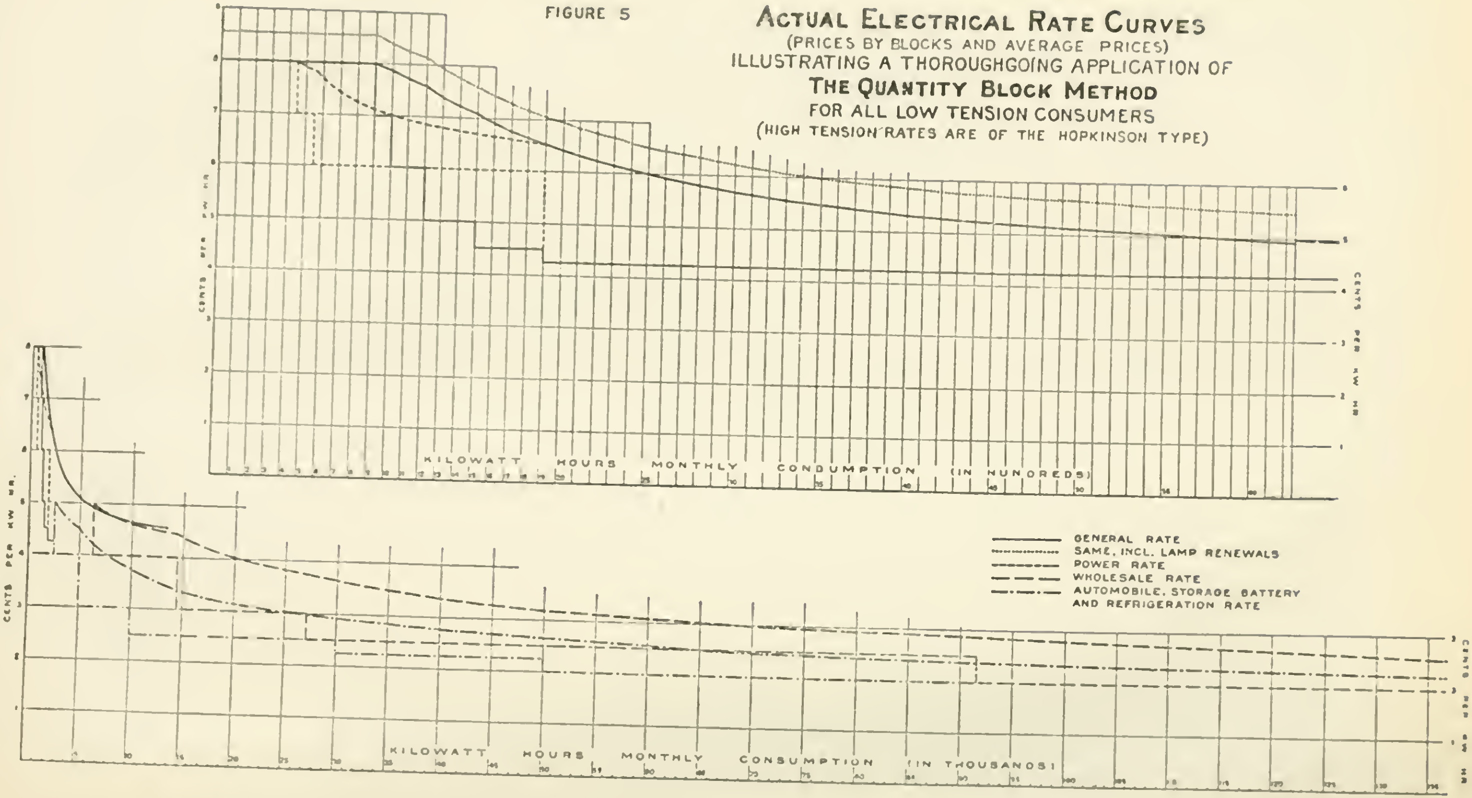
(PRICES BY BLOCKS AND AVERAGE PRICES)

ILLUSTRATING A THOROUGHGOING APPLICATION OF

**THE QUANTITY BLOCK METHOD**

FOR ALL LOW TENSION CONSUMERS

(HIGH TENSION RATES ARE OF THE HOPKINSON TYPE)



per cent of that obtained by consumers who take 900 kilowatt hours and less per month, and for the storage-battery and refrigeration class to 28 per cent.

Comparisons to determine the range of quantity discounts in the case of the Wright type of rates are not so easy to make. The rate for the small consumer in force in Chicago[7] is 9 cents a kilowatt hour (disregarding a prompt-payment discount of 1 cent) up to 30 hours' use per month of his maximum. Lamp service is included, hence the rate without lamps may be treated as 8½ cents. Large light and power consumers (low tension, A. C.) pay a demand charge of $2.00 per kilowatt per month for the first 200 kilowatts plus $1.50 for each additional kilowatt[8] and an energy charge graduated between 3 cents for the first 5000 kilowatt hours a month and 0.65 cents per kilowatt hour for all over 100,000 kilowatt hours a month, this energy charge being subject to a 10 per cent prompt payment discount. On this basis the kilowatt-hour charge for a consumer taking 1,200,000 kilowatt hours a year is about[9] 1.055 cents, less 10 per cent, and for one taking twice as much 0.8525 cents, less 10 per cent, and so on. The demand charge that goes with this can only be estimated. With a 20 per cent load factor, the maximum for 100,000 kilowatt hours a month would be approximately 685 kilowatts, costing ($400 plus $628) $1028 monthly, or 1.028 cents per kilowatt hour. The rate thus appears to be 2 cents or less per kilowatt hour for some large consumers. The range is greater than in the New York Edison schedule, but the discount in this case is not purely a matter of quantity, though the kilowatt-hour graduation shows it is mainly that. Other features of the Chicago schedule show that tenderness to quantity is by no means absent.

The above are merely illustrative cases and not extreme for electrical rates. They probably are considerably greater than ordi-

[7] 1917 N. E. L. A. Rate Book; rates involved in this calculation the same in the 1920 Rate Book.

[8] The lower second block is a concession granted only where the demand charge is on a yearly basis.

[9] The "about" is necessary because, since the energy charge is based on monthly consumption, the more irregular the distribution of the 1,200,000 kilowatt hours between the months, the lower the average rate, because a greater proportion will be charged at 0.65 cents and a less at 0.9 cents, the latter being the rate from 30,000 to 100,000 kilowatt hours a month. Cf. p. 134, above.

nary wholesale discounts.[10] Comparative statistical analysis of rate schedules generally with reference to the point under discussion should be worthwhile, but should be supported by considerable knowledge of the actual application of rates and not merely of the formal schedules.

In the above discussion the writer has attempted to isolate the quantity discount and it has been assumed for the sake of simplicity that this discount will apply to the kilowatt-hour element in the rate and that the graduation of other rate elements will be based upon other considerations. These assumptions are not entirely in accord with the facts. We know merely that the graduation of the kilowatt-hour element is properly a matter of quantity discounts, though there may also be other considerations influencing the graduation. As regards other rate elements the situation is reversed. The dominant idea may sometimes be that of favoring the large consumer, but the extent of such concessions cannot easily be measured. The demand element in the Hopkinson rate is usually graduated, either by blocks or, less commonly, by steps. It has also been noted that estimation of demand, whether under a Wright or a Hopkinson rate, may be similarly affected.

So far as these practices are due to the desire to grant quantity discounts, they are of course more objectionable, because dissimulative, than discounts relating directly to the kilowatt-hour charge. Even where a definite intention to lower the rate on the basis of mere quantity consumed cannot be alleged, the Wright type of rate lends itself so readily to the disguise of quantity discounts that there is always room for suspicion of such influence. Indeed, not much could be found to object to in such practices if the rate were worked out and put forward as based upon density-factor considerations.

The marked discounting of the demand element for size in a Hopkinson rate where the kilowatt-hour element is also discounted for quantity is not equally defensible. The demand fixed by contract, and even the measured peak, is chiefly a matter of extent of

[10] In the recent disposal of War Department canned meats by the government, as per rates advertized in February, 1921, discounts were allowed up to 35 per cent (for purchases of over $1,000,000) under the rate for a minimum $250 order. These rates have reference to getting rid of a surplus accumulated on other than economic grounds and should be greater than ordinary wholesale discounts. The minimum order accepted is not a retail lot.

premises, and therefore not directly connected with intensiveness of use. Any needed concession to long hours' use is either sufficiently provided for by the two-charge form of the rate or will naturally appear in the kilowatt-hour element.

The business of supplying with power street railways and electrified terminals and other portions of steam railroads constitutes a field of large-scale electricity supply in which the central stations are displacing independent plants more and more. Doubtless the tendency is economical. It is noteworthy that quantity discounts have little to do with the matter—nor need they, since the quantity to be supplied can be so definitely determined beforehand. As regards the load-factor, also, the demand is nearly the same from day to day, except for abnormal weather conditions in winter, so that the peak can be pretty definitely predicted or else controlled. The protection of the central-station's peak is usually specially provided for. Such contracts, indeed, do not involve a *rate,* in the sense of a price generally available to consumers on conforming to specified requirements, hence, like street-lighting contracts, are only of collateral interest for the present work.

There is a certain appearance of reasonableness in large quantity discounts. An argument may be based on load-factor considerations. A more effective argument makes implied or explicit use of the density factor, though here also the plea of the opponent of quantity discounts may be chiefly one of confession and avoidance.

The argument from the general appearance of reasonableness (the first of the two questions to be considered) is merely specious. The merits of the question raised must be ascertained. In fact the supplying of a large quantity of electricity, other things equal, costs no more per unit than the supplying of a small quantity, once the influence of consumer cost becomes inappreciable. There is no difference as regards methods of handling (which are due chiefly to vehicle and package units) as between 10,000 kilowatt hours supplied to one consumer and the same amount supplied to 1000, if consumer costs are otherwise provided for and if two other things are equal.

One of the "other" things to be considered is the relation of the time when the energy is taken to the company's load factor—a question already shown to be properly independent of the determin-

ation of the range of quantity discounts. Classification by mere quantity taken is obviously too crude to fit load-factor conditions. For some conspicuous groups it does not fit at all, notably in the case of lighting for department stores and office buildings, the use being for a short period and on the peak. Furthermore, if due recognition of the load factor is really the purpose, it is entirely practicable to register the variations of the load of large consumers and give to each of them the full benefit of his load factor and diversity as such.

It should be added, perhaps, that because of the diversity of the different elements constituting the large consumer's kilowatt-hour requirement, the computation and comparison of load factors would not of itself fully justify correspondingly low rates to him. The diversity in question would favor the company as much if each element represented a different consumer. Such large consumers usually combine both power and light. These two, though often metered separately, are ordinarily billed together; yet the company is no better off because of the mere fact that they are billed together. Their simple combination will result in a higher load factor than holds for either separately. The situation is similar as regards the load factor of a landlord who combines his tenants' consumption with his own. Diversity is not increased by combined billing. The fact that the diversity influences intermediate load factors (feeder, line and sub-station), as well as that of the electrical system as a whole, has no particular bearing on rates. At least there is no occasion to give to the large consumer more advantage from the diversity within his own consumption than an explicit load-factor rate would give.

The remaining (the second) question relates to the area within which or over which the supply is spread, that is, to the density factor. While it, like the load factor, has no necessary connection with mere quantity consumed, density is involved with quantity. But it is not to be assumed that there is a necessary connection between high density and high load factor.

The situation in question is well illustrated by the case of large office buildings. The value of the site involves an intensive use of the area and a lofty structure. Electric elevators and other electrically operated equipment, the lighting of corridors, and the free use of

energy for light and other purposes in connection with the utilization of the time of the well-paid office staff of tenants, all together involve a highly intensive use of energy per square foot of ground area or per foot of block front—a high density factor. One may also naturally infer that there is a high degree of use of connected load or maximum demand, in other words a high load factor—a strictly *intensive* use of the demand. In fact, however, the winter lighting of offices in a large city comes on before 5 P. M. and begins to drop off at that hour. Little or no regular office lighting is required in summer. The demand is therefore almost exclusively on the peak. Lighting for commercial purposes in general shows similar characteristics, but office lighting is quite the worst of the class. Even with other kinds of service to help the situation, the load factor of office buildings is bad and the diversity ratio comparatively worse. In this case, certainly density and intensiveness of use do not go together. Department stores do better, but the quality of their demand suffers in the same way. In fact, there is a degree of inherent opposition between density and diversity, as referring to a comparatively restricted area, owing to the localization of employments. In the case of mercantile establishments, moreover, the competitive situation compels general conformity to agreed-upon or established rules and practices in regard to closing hours and other controlling conditions. The earlier closing of the stores in the higher-grade shopping districts accentuates the undesirableness of such lighting demand. As to diversity, as measured by non-coincidence of peaks, there is practically none in the commercial lighting class of uses, though once the load is on, it may be continued to an earlier or later hour in the evening.

As regards both load factor and density factor the sound policy is to grant concessions specifically on these grounds and in proportion to favorableness in these respects, if this is what the electrical company wants to do, instead of obfuscating the issue by basing the rate merely on quantity taken. Existing rate schedules and practices abundantly show that load-factor considerations are easily dealt with as such. The influence of the density factor on cost has not found explicit recognition in rate schedules, but is in its nature even more easy to deal with satisfactorily.

Large power rates of electrical companies have been subject to less interference from regulatory commissions than other parts of the rate schedule, partly (it may be surmised) because it has been felt that the public generally is not directly affected, partly because competition from other sources of power is effective, especially since the consumers are themselves substantial business men, and partly because the determination of rates for such service is intrinsically a rather complex problem. It has been argued that the public is not interested in preventing the central station from taking from the manufacturer a share of his extra profits. One commission has adopted the view that a burden placed upon commercial lighting and industrial power is so subdivided and passed on to the public generally as not to be burdensome.[11] It may be noted, parenthetically, that the economist will not readily accept the notion that indirect taxes are best. On the other hand, the general public is directly concerned that power rates be not so low as to shift the burden of carrying the utility to other rate classes. Doubtless the margin on power rates has been closer than elsewhere, hence there has been a well-nigh universal increase in such rates as a result of the War.[12] Recent experience has also called attention to the fact that the quality of large industries as customers is impaired by their being affected by shut-downs and periods of depression.[13]

There are still to be considered the merely commercial or competitive, as distinguished from the technical or the strictly economic, grounds for low rates to large consumers, and the incidental tendency towards unjust discrimination by way of quantity discounts.

### The Competition of Isolated Plants

Special bargaining power on the part of the shipper or consumer is the foundation of undue concessions to him. The tendency may be an incident solely of his size or of the volume of business at stake, but this factor is usually at least reenforced by competitive possibilities of one sort or another. In the case of electricity

[11] Georgia Railroad Commission, Georgia Railway & Power case, Sept. 22, 1920. 18 Rate Research 43.

[12] Committee on Public Utility Rates, National Association of Railway & Public Utility Commissions, 1919 Convention Proceedings, pages 65–66.

[13] Massachusetts Department of Public Utilities, Athol Gas & Electric case. P. U. R. 1920C 1033, 1039.

supply the important competitive possibility is the isolated or private electric plant. Less directly, competition with steam power plants is of some importance. The central-station representatives of course claim that the isolated plant is uneconomical.

The question as to comparative economy is not easily decided. The central station has the advantages of large-scale production—and the increase of efficiency with size in the case of an electrical station is very marked.[14] A private plant, however, is not necessarily a very small plant.[15] But these advantages are not so decisive as the general student of economics may be inclined to assume. The private plant saves the fixed and operating cost of transmitting and distributing electricity, and this is as important an element in central-station cost as is the cost of generation. The private plant will usually have considerable expense for cartage of coal from which the central station may be exempt. The load-factor or degree of utilization of a private plant is not ordinarily good, while that of the central station has all the advantages arising from the broadest diversity of demand. But perhaps the most important matter is the facility of using by-product low-pressure or exhaust steam from the private plant for heating, while the central-station can seldom make much of this possibility, because condensation losses are so great on steam sent any considerable distance.[16] Large and efficient engines are also condensing engines, without by-product exhaust steam.

It may be a better description of the situation to say that the electricity needed for lighting a building in winter may be in large part a by-product of the steam needed for heating the building

[14] The case against the isolated plant in this respect is well stated by Paul M. Lincoln in a paper on the Relation of plant size to power cost, in the 1913 proceedings of the A. I. E. E., pages 1937–1948.

[15] The plant of the Equitable Building in New York City is of 2600 kilowatts capacity; that of the Woolworth Building of 3300 kilowatts. The great majority of central stations have a smaller capacity. (See page 28, above.) Plants of manufacturing concerns are commonly larger. That of the Ford Motor Co., said to be the largest direct current plant in the world (Electrical World of August 12, 1916, page 312), is of 65,000 kilowatts.

[16] Alliances of electrical with steam-heating companies, or with so-called "service" companies that manage steam plants, are a natural result. The Missouri Public Service Commission, *re* Union Electric Light & Power Co., in relation to steam-heating rates apparently designed to obtain an electrical contract, refers to the "suspicion of separate bargaining or, in other words, of potential discrimination, if not discrimination in fact." P. U. R. 1918E 490, 526. Similarly, California Railroad Commission, *re* Pacific G. & E. Co., P. U. R. 1920E 597.

supplied by a block plant.[17] The time of the need of the steam for heating, however, is not so nearly coincident with the time of the need of electricity for lighting and for elevators, etc., that the full advantage of the relation between the two can always be obtained. Refrigeration has, however, in some cases been found an available alternative to heating.

The importance of isolated-plant competition is measured from another viewpoint by the extent to which such plants already occupy an important place in supplying electricity. Entirely satisfactory data upon this point are not available, but it appears that, recently if not at present (in 1921), even after leaving out railway plants, more electricity was generated by private plants than by central stations. In manufacturing establishments in 1909, of 4,817,140 horsepower in electric motors, 1,749,031 horsepower was run by purchased electricity and 3,068,109 horsepower by energy generated by the establishments.[18] Central stations, hydraulic and steam combined, appear to have had a greater capacity. But a deduction from the central-station total for the prime-mover capacity required for manufacturing motors run by purchased power should be made (since doubtless some part of the energy purchased did not come from central stations); and a further deduction for municipal plants makes the difference in favor of the central stations small.[19] Besides manufacturing enterprises, many large office and mercantile buildings have private plants.

Data more to the point, though narrower in their scope, and which, though not official, have been compiled by or for one who is

[17] After an elaborate test of the Hall of Records power plant in New York City, making due allowance for the use of by-product steam, "the independent engineering counsel (Professors Lucke and Carpenter) have arrived at the conclusion that, if the Edison company were to sell current at a price which would be to the advantage of the city, it would not charge more than 1.46 cents per kilowatt hour, or 1.66 cents per kilowatt hour, making allowance for taxes." Letter of transmittal to printed document: Hall of Records Power Plant Report, City of New York, 1916. The test was conducted for the full year 1913. The lowest available rate of the New York Edison Company was considerably over 2 cents.

[18] 13th U. S. Census Abstract, p. 471. The 1914 Census does not show electric horsepower separately.

[19] The central station figure for 1907 is 4,098,188 horsepower and for 1912 7,528,648. Interpolation for 1909 gives 5,490,372; less some part of 1,749,031; less 416,542 (interpolated between 321,351 and 559,328) for municipal stations leaves perhaps 4,500,000. Owing to demand factor and diversity factor, even after allowing for distribution and other loss, the central station prime-mover capacity attributable to the manufacturing motors would doubtless be less than their capacity.

in position to know,[20] show the situation in the city of Chicago in January, 1912, as follows, the figures being maximum loads:

| | |
|---|---|
| Light and power stations | 100,540 kw. |
| Street railways | 186,920 kw. |
| Isolated plants | 194,300 kw. |
| Steam railroads | 146,750 kw. |
| Total | 628,510 kw. |

The last item does not refer to existing electrical supply, as the others do. Mr. Insull says that the combined load factor for the isolated plants may be assumed to be equal to that of the Commonwealth Edison Company, which is stated to be 35.5 per cent. The kilowatt hours generated by private plants may accordingly be estimated at almost twice the light and power central-station output in a city where the leading electric-supply company has been particularly enterprising in going after such business.[21]

An outgrowth of this competitive situation, of very great interest for the consideration of electrical rates, is the merchandizing contract lately prevalent in New York City for the service of office buildings and apartment houses. The situation involved is of general interest, even if not found elsewhere. Under such a contract the consumption of tenants and landlords was combined and billed to the landlord or his representative at whatever rate the quantity discounts on the total consumption brought about. This often resulted in the company's getting from the tenant little over half what it otherwise would.[22] The tenant might or might not get some small concession from the landlord. The company in either case performed substantially the same service at the same cost. But under the revision of the rate schedule effective May 1, 1915, by which the company no longer sub-meters without charge, the situation was considerably changed. The maximum rate was also cut

[20] Samuel Insull (President of the Commonwealth Edison Company of Chicago), in Transactions of the American Institute of Electrical Engineers, 1912, vol. XXXI, part 1, pp. 241–242.

[21] Insull gives similar figures of later date (Journal of the American Society of Mechanical Engineers, Nov., 1916, p. 853) as follows: Light and power business of the Commonwealth Edison Co. (doubtless including street railways), approximately 338,000 kilowatts, isolated plants, 264,500; steam railroads, 125,700; total in city, 728,200.

[22] The transfer of business from one rate class to another class with a lower rate is proposed in an able unsigned article in Rate Research, February 12, 1913, vol. 2, 1912-13, p. 303, (opinion in question on p. 320), as a sufficient check upon differentiation through lowering rates. The point of view is evidently too exclusively that of the central-station manager. But the practice of the New York Edison disregards this criterion.

to 8½ cents (and has since been further reduced), other (average) rates being reduced a larger or smaller fraction of one cent. The profit obtainable by the landlord through acting as middleman is thus much reduced but not eliminated. Previously the company had practically every expense it would have if it dealt with the tenants separately—except that the credit of the landlord might be a little better and the cost of collection reduced—since it supplied and read the individual meters and reported the readings to the landlord, renewed lamps, and attended to all matters relating to quality of service, etc. Because of the importance of consumer cost, since these tenant consumers are small, they are supposed to be unprofitable to the company, the rate being on a purely kilowatt-hour basis. But the quantity discount was applied nevertheless.[23] A contract rider practically limited the application of the method to a single block. But there are, or were, cases of such merchandizing consumers having several hundred meters.

Under the wholesale rate, however, there was a rider in accordance with which it was not even necessary for the landlord with comparatively little consumption of his own to contract on behalf of his tenants in order to get the benefit of the wholesale instead of the maximum rate, since the company counted tenants' consumption towards the minimum amount required to bring the landlord under the wholesale rate. It is obvious that such provisions had reference to the possibility of the landlord's combining his tenants' consumption with his own if he cared to install his own private plant. The competitive situation, not cost, determined the rate policy of the company at this point.

The rate schedules of other companies than those of the New York Edison and the associated United Electric Company doubtless accomplish the same thing, but not so directly.

It should be added, however, that the corridor lighting and elevator service of the landlord is in effect an extension of the service of public ways and may on that ground be considered entitled to favorable differential treatment, so far as the costs imposed upon the company allow.[24]

[23] "When the wholesale is merely the bookkeeping aggregate of numerous retail deliveries the principle . . . . applies to a much lesser degree." Report of the Rate Research Committee, 1915, N. E. L. A. Convention proceedings, Commercial vol., p. 339.

[24] Washington, D. C., and Seattle, Wash., offer special rates for public lighting in apartment houses.

Where a landlord, while performing no substantial service in this connection for the tenant, receives a considerable share of what the latter pays for electricity—supposing of course that this service is metered and billed separately for the tenant—it would seem that the situation constitutes a clear case and a most reprehensible form of rebating, morally if not legally. The better commercial credit of the landlord cannot, in view of the other means available to the electrical company to insure collection and of the inferior facilities of landlords for this purpose, be considered compensatory. But the abolition of gratuitous submetering doubtless changes the legal situation.[25]

Whether there are special inducements of which rate schedules give no evidence by which potential consumers inclined to operate isolated plants have sometimes been persuaded to take the central-station service, is an administrative question of some interest, but not a matter with which a general discussion of electrical rate theory and practice can deal to advantage. It may be noted in passing that such things might occur in connection with the wiring of consumers' premises, charged to "promotion of business." Companies sometimes supply auxiliary services and appliances and first installations without regard to direct cost but rather with reference to extending consumption. Misclassification, also, which may be somewhat more difficult for an electrical than for a railroad company, is not impossible. Since the companies attach so much importance to getting the business of the large consumers, it would not be surprising if the latter were found to be specially favored in ways not appearing in published rate schedules. That this sort of thing is common commercial practice in other fields is a sufficient reason for watchfulness in the case of public-service corporations. How prevalent and persistent it has been among the railroads is well-known. A corporation whose policies are open and

[25] The use of private telephone exchanges in hotels and apartment houses is somewhat analogous to the combined metering of electricity consumed by tenants, but it seems not to have been done for the sake of direct profits and therefore not often to have occasioned disputes. There is one interesting case, where a hotel attempted to collect 10 cents a call for both room service and public corridor booths. The telephone company tried to adjust its rates to permit the practice. The Massachusetts Public Service Commission's decision prohibits hotels from purchasing telephone service in bulk and selling it at retail on the ground of lack of authority on their part to deal in such service, holding it to be immaterial whether the hotel sought to obtain profits from the service or not. 14 Rate Research 229–235.

whose heads are public-spirited, however, should not be subject to suspicion.

Although large concessions for large quantities consumed seem to be the natural means of meeting isolated-plant competition, this method may not be the soundest. The private plant ordinarily has a poor load factor. While the central station itself may not be so decisively concerned with the individual load factor of the large consumer (because of the advantage it obtains from diversity), unquestionably the variation of cost to the operator of a private plant is much affected by it. Under these circumstances it would seem to be unnecessary that the central-station company should give the same rate to all large consumers regardless of their load factors. In other words, even with reference merely to meeting most effectively the competition of the isolated plant, the wholesale rate should be a load-factor rate. Such a rate conforms best to the variation of isolated plant cost.[26]

Although isolated-plant competition is so likely to cause discrimination, the situation has also its positive aspect. Apart from general arguments in favor of large-scale production and supply—another name for the density factor—as reducing cost, density has very special importance in the case of electricity supply because of the large proportion of total cost due to transmission and distribution—a proportion usually as great as, and often much greater than, that employed in production proper. For this comparison transmission cables and sub-stations are part of the distribution system. The ratio in question varies extremely, of course, especially according to the type of electric line construction, and is, for this and other reasons, greatest in the largest cities. The burden of fixed costs on this account is reduced in proportion to the density of consumption within the field supplied by the central-station company, and such density is chiefly dependent on whether it gets as much as possible of the electrical business within its territory. A feature of the New York Edison Company's rate schedule that is from this point of view justifiable is the restriction of quantity discounts to the city-block basis. This policy results in some approximation to the density-factor basis.

[26] Mr. Ives, in the Electrical World, Apr. 17, 1915, vol. 65, p. 989, says this point is "the strongest argument in favor of a load-factor rate."

In this connection it may well be noted that the great steam central-station company with the largest type of alternating-current turbo-generators, high-tension transmission lines, and a score of substations is technologically as different from a small-town plant as it is from the private plant of an office building.

The desirability of concentrating the generation of electricity as a matter of war economy in order to save coal was called to the attention of the public by conferences and press notices in March, 1918. It was proposed that large numbers of isolated plants ought to be shut down. The proposal applied for small central stations as well, and was accompanied by a suggestion of the joint utilization of some such small plants, instead of their being merely shut down.[27] General economic conditions during the War, especially the difficulty of obtaining fuel, naturally worked strongly in the direction of substituting central-station for isolated-plant service. The annual report of the President of the Consolidated Gas Company (New York City)[28] records 72 private plants displaced by its subsidiary electrical companies during 1918. In fact the tendency of isolated plant owners to turn to central-station service as an escape from high coal costs and the difficulty of getting supplies has often occasioned embarrassment to the latter.[29]

While it is correct in general to treat carrying charges on the distribution system as a joint cost, it should be noted that in the case of large consumers it is often possible and proper to separate this element in cost. Such a consumer may have a feeder direct from the sub-station for his individual use, which becomes thus in effect an expensive individual service connection. Such a feeder is more separable and more properly chargeable to the individual consumer than the regular service connection between the street main and the interior wiring of a multiple dwelling. It will very likely still be true that the *average* cost per kilowatt or per kilowatt hour for the distribution of energy to large consumers will be mark-

[27] Mr. C. E. Steuart of the Fuel Administration at hearings before the New York Public Service Commission for the 1st District. Note in Electrical World for March 16, 1918, page 582.

[28] February 15, 1919. (Reference in Electrical World, page 335.)

[29] On which subject the Sandusky Gas & Electric Co. says: "We are compelled to buy coal at present prices and generate electricity to be sold at before-the-war prices to consumers who have taken advantage of our predicament to such an extent that anything like good service is impossible." Electrical World, June 19, 1920, p. 1448.

edly lower than the corresponding average for small consumers. But the *separable* cost that fixes the *minimum* limit to rate concessions arranged by the differential treatment of joint costs will, as regards this element in the total, be greater, not less, for the large consumer. In general the smaller the consumer, the greater the proportion of transmission and distribution cost that is joint, or rather the more nearly complete is the disappearance of the separable element in such cost.

### The Opportunity for Diversification and Intensification of Use Among Small Consumers

Electrical companies commonly show great interest in the large consumer—to whom competitive options are open—and comparatively little interest in the small consumer, not only the residence-lighting but also the small-power class. As a matter of fact, the "residence lighting" designation ought soon to become a misnomer. Indeed the so-called "general rate" is replacing the "retail lighting rate" in current terminology. This is partly due to a tendency in the most developed centers to discontinue substantially the distinctive class rate for power. Thus all small consumers, and some that are in fact not very small, are, or shortly may be, in the same situation as regards electrical rates.

One of the great economic—and social—reforms that the electrification of power appliances generally may legitimately be expected to bring about is the removal of one great disadvantage under which small manufacturers, including the so-called hand trades, have suffered in competition with large factories. It is impossible for the former to obtain their power economically directly from steam on so small a scale or in so manageable a form as they require. Central-station electricity admirably meets the need of morselized power supply. It can bring power-driven machinery down to the dimensions of one man's management and take from mere mass of capital its great advantage in this respect. Flexibility and ease of adjustment to the use in hand are advantages in which electricity has no competitor. Shall the great public-service enterprises be allowed to hinder such a development because of the competitive club held over them by the large concerns? The small power user often has to pay five times as much per kilowatt hour as the big

manufacturer or the large operator in other lines. The electrical enterprises appear to feel too sure of this class of business to find out what its possibilities of expansion are.

In residence applications, also—aside from the advantages of residence lighting over mere commercial lighting—[30] there are great possibilities of which only the beginning of an exploitation has been made. Motor operated cleaners, washers, freezers, etc., have as yet hardly passed beyond the stage of curious interest. Electric refrigeration is in principle just as well worth promoting in the home as in the factory. Cooking, especially such parts of it as may be done at the table—toasting, percolating coffee, etc.—ought to develop more rapidly than it does.[31]

Heat uses as such are not economical—a point well illustrated by the fact that it requires the employment of two-thirds of a horsepower to heat the electric iron in common domestic use. Regular cooking by electricity is likely to remain too expensive under any general kilowatt-hour rate that can at present be foreseen. But the combination of the fireless cooker plan with an electric heating element ought to be highly economical of direct cost as well as highly convenient. The common objection that the heaviest demand for cooking (for dinner) comes just at the peak hour scarcely applies for the insulated type of appliance. And most industrial power uses similarly come on the peak. Electric cooking is also likely to a considerable extent to constitute a special summer demand. During the day, also, it fits into the noon-hour valley of industrial use or, at breakfast, comes ahead of the industrial demand.

Heating of rooms by electricity is probably still some stages removed from practicability except in the homes of the very rich, or in regions supplied by underloaded hydro-electric plants, but summer heating may not be impossible. Only water power under conditions of minimum use of flow seems quite equal to meeting the low-cost requirement necessary for the general-heating use. This off-peak condition has been met to some extent, perhaps experimentally

[30] Because of "early closing precluding consumption by stores of more electricity than residences," the Montana Range Power Company was held to have an improperly balanced schedule in charging residence customers 12 cents an hour against a merchants' rate of 6½ cents. Electrical World, June 19, 1920, page 1449.

[31] An Electrical World editorial (Feb. 7, 1920, p. 305) refers to the "potentially gigantic power load in our homes."

rather than altogether practically, by storing the heat in water.[32] Technically heat can easily be stored for a few hours while power and light, economically speaking, cannot be stored. Electric ironing, on the other hand, though it is also a heat use, is of established practicability and economy. But the use of electricity for house heating is in general not economically practicable.[33] From the point of view of the electrical company, moreover, the load factor for atmospheric heating it bad.

It is true there is a very effective competitor for electricity in much of this field, especially as regards cooking, in the form of centrally supplied gas. One might expect this competitive opportunity to stimulate the ambition of the electrical companies to get the business. The two classes of utility, however, often seem disposed rather to divide the field. From a general point of view, it should be noted that in gas cooking the circulation of air through the flame is necessary, and this inevitably carries most of the heat away; also the savory volatile essences of the food go with the air currents. Electricity on the other hand is specially adapted to insulated cooking. Perfect control of temperature is one of the advantages of electricity in this application that should count for much in cost and service comparisons. In the western part of the United States, it seems, the electrical companies have given much attention to the promotion of electric cooking, but not noticeably in the conservative East. In general, the greater the nearness and closeness of the application to consumption and enjoyment, the less considera-

[32] The method appears to be a practical success in Norway. Heat-retaining stoves are similarly heated at night in Switzerland.

[33] A "Report on the Heating of Houses" by the Hydro-Electric Commission of Ontario, Feb. 28, 1918, states the gist of the matter thus: "Coal at $10.00 per ton is very much cheaper than electricity at 0.35 cents per kilowatt hour." The report also points out that the room for prospective increase in efficiency in the burning of coal is great while in electric heating it is small. The Idaho Commission, which has to do with hydro-electric companies largely, says that "so long as there remains a field for the use of electric energy as motive power, its use for house-heating is extravagant and wasteful." Electrical World, Nov. 29, 1919, page 1021.

On the other hand, it is predicted by D. D. Miller (Electrical World, October 12, 1918, page 693) that the industrial heating load will eventually surpass the industrial power load. But this means that certain heat uses in the chemical industry where mode and control of application of heat, rather than its quantity, are fundamental, will become increasingly important.

tions of cost will prevail over those of convenience. Even so, the domestic heating field is not promising for electricity.[34]

Mechanical-power uses in the household are more economical of energy than heat uses, but their development without special encouragement will probably be slow. Vacuum cleaners, washing machines and wringers, electric fans, and sewing machine motors are only the more important among the possibilities. Refrigeration and occasional heating in the summer season are applications appropriate to the household that may be expected to become common in the not distant future. Their development should be of particular interest to the electrical companies as tending to correct the undesirable seasonal variation of lighting uses. Reference to the wattage[35] of such motor and other appliances and to hours' use in comparison with that of ordinary lighting requirements make it evident that their adoption, together with the further spread of incidental heat uses, might easily double or treble the energy taken by residence consumers, among who the only regular use of electricity at present is for lighting. This would mean diversification of use, thus bettering the residence demand in respect to what may be called quality, but still more decisively, it would mean intensification of use and density of demand. The gains to be made in the domestic field are not less in proportion than those to be obtained through putting the isolated plants out of business.[36]

It should be mentioned again that the urban lighting field is far from being as fully occupied by electricity, with regard to small consumers, as would seem desirable on economic grounds. The hold of gas lighting in this field is doubtless being steadily encroached upon. But much remains to be accomplished, as is indicated by the fact that consumers of gas in New York City are more than four times as numerous as consumers of electricity;

[34] The technical disadvantage of cooking and heating loads has been the subject of a warning by Arthur Wright to American companies inclined to encourage such business. Thermal efficiency requires close regulation of voltage and its full maintenance, which is costly and is comparatively unimportant for metal filament lamps. Compare 1917 Rate Research Committee Report, pages 181–2.

[35] The 40-watt tungsten lamp is a standard lighting unit. Toasters, flat-irons, percolators, and grills are of about 500 or 600 watts each; vacuum cleaners and washing machine motors of about 200 watts; electric fans and sewing-machine motors of about 40 watts.

[36] The Utah Public Utilities Commission, *re* Moab Light & Power Co., in authorizing increases in rates, required the company on load-factor grounds to include household electric appliances within the benefit of the cooking and power rate. P. U. R. 1919F 948.

and the ratio is probably not much smaller for American cities generally. How far the displacement of gas as an illuminant should go depends on comparative costs. In terms of candle hours and at prevailing prices for small users, doubtless the direct comparison of the standard tungsten lamp with the Welsbach mantle gas burner is still somewhat unfavorable to the former. The elements of cost and utility favorable to electricity that are not taken into account in this way, nevertheless, probably justify the claim that electricity is already the most economical illuminant under practically all circumstances.

Lack of density of demand is probably at present a greater drawback of residence neighborhoods in large cities than bad load factor. But the possibilities of the situation should be decidedly encouraging to the electrical companies. Much is already being made of electricity on the farm under conditions far less favorable in this respect, the general rural use of electric service being as yet out of the question.

The special cooking and similar rates in actual use have commonly a low kilowatt-hour charge but a high maximum consumption guaranty. It would be better to adopt the general rate to the possibilities in question by lowering the kilowatt-hour rate and coincidently protecting the revenues of the electrical company by a consumer or other service charge. Or an existing rate system can be adjusted by rating each consumer for expected ordinary use and allowing a low rate for excess consumption. In either of these ways even the smallest consumers would be encouraged, not only to improve the form of their load curves, but, also to contribute greatly to density of consumption. As to an excessive maximum demand resulting from the coincident use of nearly all the appliances in a household at once—the supply company can control the situation by limiting switches, double-throw switches (making cooking and water-heating alternative to each other, for example), and possibly by means of devices to record or control the demand at the time of the station peak.

Reference has already been made to the possibility of bettering the station load factor by increasing diversity of domestic use through stimulating the sale, or in some cases providing for the rental on easy terms, of domestic appliances.[37] Increased density

[37] See Chapter V.

of consumption is an even more certain and quite as important a source of prospective gain from such a policy. The policy of encouraging such consumption by pushing sales of appliances is much in evidence on the Pacific Coast and also to a nearly equal degree in the Middle West. Despite war conditions, the Commonwealth Edison Company of Chicago sold $1,000,000 worth of merchandise in 1918,[38] which was increased to about $2,500,000 in 1919.[39] It should be of advantage to rent, as well as sell, the more expensive appliances like washing machines. It is possible also that less sympathy for "price maintenance" theories in these matters would be of advantage to the electrical companies.

At the 1919 N. E. L. A. Convention it was predicted[40] that in the next two or three years the largest growth in central station business would come from increased consumption by home devices and from the substitution of central supply for isolated plant generation. The rate policy of the company represented by the speaker might color his expectations as regards the latter, but not the former, tendency. The public-service character of the electric supply industry should mean emphasis upon such service to the greatest number, of course within the limits fixed by costs.

The defects of the Wright rate from the viewpoint of load-factor considerations have been noted and it has also been hinted that, if reconsidered and readjusted with reference to density-factor considerations, its claims for more general employment might be greatly strengthened. The basic estimated kilowatt requirement would need to be little changed. But the adoption of a consumer charge might properly involve reciprocal modification of the so-called primary rate per kilowatt hour. This should mean, perhaps, a lower primary, but in any case an earlier reaching of the secondary, kilowatt-hour charge. The limit of the first block—the point of incidence of the "follow-on" rate—should be determined much more according to definite principle than appears hitherto ever to have been done. The number of hours use of the "maximum" per month required before the consumer gets the benefit of a lower rate has frequently been adjusted to encourage cooking—why not to encourage domestic uses

[38] Electrical World, Feb. 8, 1919, page 277.
[39] Electrical World, Dec. 20, 1919, page 1120.
[40] By Arthur Williams of the New York Edison Company. Electrical World, May 24, 1919, pages 1080–1081.

in general? The ground for the adjustment in either case is the density factor. The limiting of the count for active connected load to lighting has a similar effect. The discussion of the "follow-on" rate by the 1917 Rate Research Committee shows how haphazard has been the adjustment.[41] A beginning of a conscious policy of emphasizing the density factor and intensive use might be made at his point.

### How Volume of Consumption May Best be Recognized

Volume of purchases is generally recognized in all lines of business as a sufficient reason for specially low prices. This is because of the smaller unit cost where articles are handled in large quantities. But the practice rests also upon the familiar general ground of differentiation, that is, the profitableness of rapid expansion through the acquisition of large quantities of new business. Of course the possibility of profit on account of the latter is conditioned by prices being kept above the limit of the separable cost of serving the large consumers. The justifiability of the policy of wholesale discounts rests upon cost analysis. But a company may possibly be clubbed into undue concessions by the special bargaining power of certain consumers—as the railroads have often been. It is also quite possible for a dealer to overreach himself in his anxiety to get large orders. In the case of a more or less monopolistic public-service corporation such a mistake might not reveal itself by its natural consequences, since the company could make up the deficit on the favored class of customers by higher charges elsewhere.[42]

The difficult problem for cost analysis in this case is where to draw the line between separable costs caused by the particular service in question and general or joint costs that would have to be incurred whether that service were performed or not. Into the details of this analysis it is not necessary to enter here. It suffices to say that any class of business that hangs in the balance will be likely to have its separable cost reckoned closely.

[41] N. E. L. A. Convention proceedings, General volume, pages 178–181.

[42] The 1917 Rate Research Committee report refers disapprovingly to "the questionable drift toward a 'block rate' for all services large or small regardless of load factors, and the very dangerous inclination to fix a maximum rate approximating what should be an average rate." Convention proceedings, General vol., p. 177. The latter tendency is very properly associated with the former, as appears in the discussion of consumer cost from various viewpoints in this book.

There should be noted in this connection, however, a point to which attention has been called above,[43] namely, that the sum of the separable costs of all classes of business added together will not equal total cost. There will be a very considerable difference between these two, which is accounted for by such cost elements as cannot be said to be due to any one class of business. Cost analysis confesses itself wrong where separated costs do add to the company's total. When this happens it often means that the costs for one class have been determined as residual, this class taking up everything that is not already accounted for elsewhere.

A comprehensive total unit-cost may also be obtained by carrying the process of apportionment through joint cost according to some more or less arbitrary scheme. The method of such apportionment is a matter of opinion, and the results ought not to be treated as of the same nature with separable costs. The plan of apportionment might better be applied to the undistributed cost as a conscious attempt at differentiation according to ultimate profitableness or to ultimate costs, so far as predictable, both these plans amounting in the long run to the same thing.

The rate made to the very largest consumer should deal with the class, not with the individual as such.[44] The danger from dealing with each individual separately is peculiarly great in the case of consumers especially interested in quantity discounts. Even if a particular consumer constitutes a class by himself in respect to size, he need not be treated as an individual to be bargained with separately. The rate schedule should provide for the largest class of consumers by graduations shading into each other, just as the retail and wholesale rates should shade into each other. As to load-factor considerations, also, the adjustments of the rate schedule should similarly anticipate all needs. Special contracts not suggested by the plan of the rate schedule are justifiably condemned.

There are reasons why one might expect the range of quantity discounts in the case of electrical rates to be small. We may assume that consumer costs are taken care of by a service charge of some

[43] At page 86 ff.

[44] The Washington Supreme Court (State ex. rel. P. S. C. of Washington *v.* Spokane and Inland Empire Rr. Co., P. U. R. 1916D 476): "'Rates' must be held to mean a charge to the public for a service open to all and upon the same terms, and not a consideration of a private contract in which the public has no interest."

sort. If they are not so disposed of, we should expect them to be absorbed in the initial or earlier rate blocks, thus having no appreciable effect on the range of quantity discounts. As regards the matter of delivery in small lots as against "bulk delivery," there is no reason here for a considerable range of discounts, since all low-tension delivery is under substantially the same conditions. Units are not discontinuous; there is nothing corresponding to the carload lot of the railroads. There are no expenses for packing and handling. Selling expenses and the cost of making a market are unnecessary.

On the other hand, quantity of demand may be presumed to be associated with density of demand. In so far as this holds, there is a basis for a broad range of discounts. It is true, also, that this factor is nowhere more important than in electricity supply. The transmission and distribution system costs about so much, whether much or little energy is sent over it. As regards the amount of copper employed, that will have to vary with the quantity of energy supplied, except so far as increase in the quantity supplied is due to longer hours' use. But all the other expenses of electric-line construction will in any case not greatly increase with the increase in quantity supplied in a given area. Extensions to new territory are, of course, a different matter.

The degree to which this factor, which is the density factor, is of special importance for an electrical corporation is measured by the amount of its investment in transmission and distribution. The proportion of such capital to total electrical fixed capital—in which connection it should be remembered that the total in question is itself accountable for a conspicuously large proportion of the cost of electricity—is, as has already been shown, especially large. But if the density factor, that is, the degree to which current is supplied within the limits of a given area—as measured, for example, by kilowatt hours per year per foot of block front—is a sound basis for discounts, is it not evident that the lowering of the rate should be pursued in conformity with this principle of variation instead of merely according to quantity taken?

Actual rate practice is far away from correspondence with what regard for the density factor would indicate. The application of the quantity-discount principle by the New York Edison Co. forcibly illustrates this point, in the general principle underlying the sche-

dule as well as especially in the "merchandizing" contracts fostered, both of which matters have already been discussed. Perhaps it is just that the rate should be low under the circumstances prevailing where "merchandizing" obtains, but if so, should not it be such in proportion to the benefit of the density factor and should not the rate be substantially the same on the tenant's consumption whether made to the tenant or to the landlord? Merchandizing contracts are apparently a logical result of the company's willingness to sub-meter to any extent the consumer may desire. If so, there should be a charge for this service. And that would properly involve the general application of a meter charge.

But the reasonable explanation of such policies is isolated-plant competition. It would seem that this method of meeting such competition is anything but satisfactory from a public viewpoint. On the other hand, so far as concessions are made on the basis of the density factor, there should be no objection to them in principle. If the central-station company's territory is dotted with isolated plants, it cannot make so high a degree of use of its transmission and distribution system as it would if it had practically all the business, hence if the serving of this class of consumers hangs in the balance it is justifiable for the company to compute cost without including more than a minimum amount for transmission and distribution. Such a degree of differentiation would inure to the benefit of all.

The situation with regard to some large consumers, however, is modified, as has already been noted, by reason of the fact that they may be supplied by a direct line from the generating or sub-station instead of from the regular distribution system. Doubtless the cost per kilowatt hour for capital outlay and maintenance is in such cases very small. But such cost is in this case *separable,* hence the argument for low rates to large consumers is, so far as it rests on the differential theory, weakened rather than strengthened by such conditions.

A calculation that determined costs per kilowatt hour for the most favorable conditions as regards density would fix the proper minimum rate obtainable on account of volume of consumption at one place. This point once fixed, the policy of the company should be undeviating, regardless of whether isolated plants continue to be installed and used or not. The policy of an electrical company

should be unambiguous and undeviating because, from any point of view, isolated plants should not be built merely for bargaining purposes. Purely "business principles" are not likely to lead to the best results in such a situation. And in fact the protection from competition enjoyed by a public-service corporation should properly stop it from applying in the conduct of its business narrowly commercial, as distinguished from broadly economic, principles.

The central-station manager naturally seeks to displace rather than to cooperate with isolated plants. For this reason little use has been made of a possibility of mutual advantage in dealing with the situation. Because of the value of steam for heating in cold weather the isolated plant's cost per kilowatt hour of electricity is greater in summer than in winter. The unfavorableness of the summer situation of the isolated plant tends to be heightened by the increased efficiency of lamps and the lessened need of energy for this use. The central-station, on the other hand, needs the summer business most. It should perhaps extend to private plants the advantage of a seasonal off-peak rate.[45] The central-station cannot to advantage itself sell exhaust steam for heating, because its engines are of the condensing type as well as because it is seldom near enough to the business center.[46]

These suggestions should, however, await the spirit of cooperation on both sides. The isolated plant cannot rightly claim any advantage of cooperation and at the same time the unrestricted right to compete.[47]

[45] The diverse attitudes of central-station men towards this suggestion is shown in connection with a report on High Load Factor and Non-peak Business and the ensuing discussion in the Commercial Sessions volume of the 1914 Convention proceedings of the National Electric Light Assn., pp. 289, 290, 293. The economic advantages of the use of private plants to supplement central stations at peak times is discussed in a paper by Moses and Schaller, Co-operation between central-stations and private power plants, in Power for June 12, 1917, p. 812 ff. Articles by central-station men favorable to the idea may be found in the Electrical World for July 24, 1920, and for Jan. 1, 1921.

[46] There is a possibility in the use of gas for lighting in winter when the heat adds to its utility, and of electricity in summer when the heat is of negative value.

[47] Mr. Lieb of the New York Edison Company states the viewpoint of the central station, though perhaps putting the case too strongly, as follows: "We are prepared to give 'segregated' service as an auxiliary to private plants at our regular rates without any limitations whatsoever. We are also prepared to give breakdown and auxiliary service to isolated plants at the standard rates for this service provided for in our rate schedule. We are not, however, prepared to furnish breakdown service to a so-called block lighting plant, which is not a customer's own plant furnishing service for himself alone, but is in effect a small central station supplying energy to a number of customers outside of the building in which the plant is located, making it an actual competitor of the lighting

As to the method of applying the density-factor principle, the foot of block front, in view of its relation to the extent of the distribution system, would seem to be the best basis. Density-factor discounts should be figured per kilowatt hour consumed per foot. But this is suggested tentatively only. Administrative details and difficulties to be met in applying such a principle do not need to be discussed here. Some account might need to be taken of the number and character of service connections for the block. But such discounts have no proper dependence upon whether the consumers in a block —granted a certain volume of consumption—are one or many. The rate should be based upon the aggregate consumption in the block. But if some one or another consumer can be distinguished as taking more kilowatt hours in proportion to the space he occupies in the block than others, it is possible that rules might be devised to give such a one a larger share of the discount.

The central-station manager may feel that it is no merit of the small consumer—for example, a residence consumer in a multiple dwelling—if he happens to live under conditions such as cause the consumption of a great quantity of electricity within the limits of a single block. Such a manager may also entertain along with this opinion the notion that it *is* a merit in the large consumer, perhaps a hotel proprietor or a manufacturer, to contribute to density of consumption by taking his electricity from the central station. But such a distinction would certainly not commend itself to the public as fair, and even as a matter of private business, it should not be forgotten that an increase in kilowatt hours distributed per acre is a matter of relative, not of absolute, quantities. It is obvious that increasing the consumption of a given number of residence con-

companies, one over which the commission has not, however, assumed jurisdiction, these block lighting plants paying no franchise taxes and escaping the regulatory obligations and control as to rates, standards and conditions of service, etc., that are imposed on lighting and power companies by the Public Service Commissions law and the statutes of the State." See p. 583 of Electrical World, March 16, 1918. In the case of Acker, Merrall & Condit Co. *vs.* the New York Edison Company (Dec. 31, 1918), the New York Public Service Commission for the 1st District decided the company had no right to refuse service to a block lighting plant, because the company cannot pick and choose among possible customers and because it does allow merchandizing customers to resell energy in their block. The mere operating of a generator is held not to make an electric plant in the sense of the law and not to be an essential difference. P. U. R. 1919B 287. This decision was reversed by the N. Y. Supreme Court, Feb. 1920, on the ground that the company should not be compelled to supply breakdown service to a competitor. 181 N. Y. S. 259. This decision has been affirmed by the Court of Appeals, the court of last resort in the state.

sumers is *pro tanto* as important as increasing the use of central-station energy by any other group of equal weight.

Density is not a matter of the size of the consumer, but of getting all sizes and increasing all. Elasticity of economic demand is not a function of size; and there are general economic grounds, fundamental to the nature of the curve of diminishing utility and economic demand, for believing that elasticity of demand is greater at comparatively high prices than at low prices[48] Consumer cost having been properly disposed of, there is no reason why the small consumer should not get as much proportionate advantage from density as the large. That central-station men think too much of bargaining power in this connection is evidenced by the fact that they are willing to deal with an aggregation of small consumers as if combination affected the character of their demand (in the economic sense). It is true that all merchants do likewise, but the conduct of a public-service corporation protected from competition can be and should be different. The ambition of the commercial management of an electrical company to get all the business of all the *large* purchasers may easily exceed due bounds.[49]

The selection of the street block as the appropriate unit for computations relating to density is of course in part merely a matter of convenience. Some other unit might serve the purpose better in some localities. But there is a possible general objection to any such basis, which should be considered. It might be alleged that density of consumption is purely a question of distance from the central station and that what is called for is the favoring of nearby or centrally located consumers. There are important reasons why such an argument is not sound.

The location of a generating station within the district it serves is determined mainly with reference to available facilities and costs of production and only to a very minor extent with reference to nearness to the centers of largest consumption. Technical as well

[48] "The elasticity of demand is great for high prices, and great, or at least considerable, for medium prices; but it declines as the price falls; and gradually fades away if the fall goes so far that satiety level is reached." Marshall, Principles of Economics 5th ed. p. 103 (Book III, ch. IV, par. 2).

[49] The classic argument for direct in preference to indirect taxation might be applied on behalf of granting a rate yielding little profit in the case of manufacturers and others who use current for purposes remote from consumption, but the writer has nowhere seen it so applied.

as commercial considerations (the latter having to do with the transportation of fuel and the former perhaps chiefly with the supply of water for condensation) favor a waterfront generating station. Transmission at high tension, furthermore, is much more efficient than distribution at low tension. Hence, whether a particular group of consumers, or a particular block, is nearer to the station than another is an accident that should not affect the rate.[50] In the case of outlying territory not offering enough business to use the distribution system sufficiently, of course, distance may, in one way or another, be made a factor in the rate, but not merely on density-factor grounds. The fact that private-residence consumers, even in well built-up sections, are on the average at a greater distance from the generating station than other classes is sufficiently recognized in any attention paid to the density of their consumption. Moreover, their average distance from the sub-station, or their necessary average distance from a sub-station of standard efficient capacity, is of greater significance.

How far extensions should be made that cannot be expected to pay for themselves for some years and must meanwhile be carried by the general business of the company is a question akin to the one just discussed. But it is at least a much larger problem, indeed too large for incidental treatment here. Adjustment of rates with reference to notions of equality of rights may easily carry the imposition of public duty so far as properly to involve taking the administration of the utility out of the hands of the private corporation.

Disregard of distance (within reasonable limits) as a factor in rate-making—except, of course, in so far as the general average

[50] The economic point along with others is contained in a Wisconsin decision in a gas case in the following: "Legally there is no objection to basing a rate schedule upon distance differentials which will take care of the accumulating costs created by serving customers at increasing distances. This form of schedule when applied to different distances within any city is objectionable, however, from a social point of view in that it discriminates in favor of the central portion of the city which tends to become congested at the expense of districts farther removed. It is also objectionable from an operating standpoint in that it might interfere with good engineering practice relating to the location of gas plants. Franchises have therefore usually required that a uniform rate apply to all sections within which the utility is authorized to operate. This has been the case in Milwaukee. But as between two municipalities, these arguments do not apply and for this reason the West Allis rate schedule must be based upon its separate cost data." Wisconsin Comsn.—City of West Allis, *vs.* West Allis Gas Co. Apr. 19, 1916. 9 Rate Research 367.

distance of transmission and distribution must be provided for in general average rates—is in principle the same as the disregard of the character and cost of the local distribution system, as to whether it is alternating-current or direct-current, underground or overhead, etc. If such conditions were made determining elements in rates, regulating commissions would need to prescribe methods of construction in greater detail than they now prescribe types of consumer's meters to be used.

As to commercial policy, the rule "to divide and conquer" applies in relation to density as in other respects. Where density is low, the effect of encouraging more intensive consumption is likely to be greater than in the fully developed center of a city. If an isolated street block in an outlying section gets a low rate by reason of density, that fact is of incidental advantage to the company as an example to neighboring blocks. Within the established limits of the distribution system, a single system of density discounts should be impartially applied. It is hardly necessary to specify that density is a matter of ground area, not of floor space. But a rate based on floor space—as the Wright rate sometimes is—has density-factor characteristics.

Under special conditions there may be sufficient reasons for granting a "development" rate, of an experimental character, to a class of large consumers, but in relation to all such actual or alleged exigencies it should not be forgotten that the density-factor rate should itself be by nature the greatest developer of business.

What should be the minimum rate per kilowatt hour obtainable merely by density-factor discounts depends upon specific conditions of operation. But some general propositions can be enunciated. Such discounts will naturally apply when load-factor considerations do not. But the two ought to be applied in conjunction, and the combined result must be carefully calculated beforehand. On the score of density discounts alone, it would seem to the writer that the kilowatt-hour charge might decline—of course regardless of the absolute amount taken—to the level of the average wholesale rate, which would mean a discount of about half the maximum kilowatt-hour charge. Such a minimum should be subject to still further discounts on account of load-factor considerations.

The foregoing discussion of quantity discounts assumes a homogeneous supply, i. *e.*, low-tension energy supplied under ordinary

residence, store, office, or shop conditions. High-tension energy is different, since it is furnished in a comparatively raw state and has to be worked over by the consumer with rather expensive appliances and specially handled on account of fire and casualty risk. Hence the high-tension rate may well be lower than the lowest low-tension rate. This, however, is a special matter that need only be mentioned in a discussion of the general foundations of electrical rates.

The making of the density factor an explicit element in rates is of the greatest practical importance in the sense that it seems to be the only satisfactory way to deal with a problem that causes more trouble than any other phase of differential rates. Such a device would remove arbitrariness, which has been the bane of differentiation. It would give the devil—in this case presumably the large consumer, though it may sometimes be more nearly correct to identify him with the other partly to the arrangement—his due. Giving him his due is a necessary means of preventing his getting more than his due. It would cut the ground from under the specious argument that the load factor of the large consumer entitles him to special consideration on account of his size. The fact is merely that the volume of his consumption means the inclusion of much diversity within that volume, due among other things to the use of both light and power—a situation of no more advantage to the company than it would be if the different uses were metered separately and billed to separate consumers. The "increment-cost" analysis so often applied in this connection is also to a great extent merely specious because it supposes that the last comer is to be credited with all the density obtained, not always *through* him, but often merely *with* him.

From an economic viewpoint, it is *density* of consumption that the central station needs; not large consumers as such, still less composite or "merchandizing" customers. If, in order to maintain density of consumption, it is necessary to grant low rates to loft and office buildings and apartment houses, it would seem best to make the density factor explicit in the rate schedule; that is, to grant discounts from the maximum rate on the basis of kilowatt hours consumed per month or year per foot of block front, or according to some other convenient and practicable measure of density. Such discounts should not depend upon whether the con-

sumers within a given block are billed separately or through the landlord; although, for reasons of administrative cost, it could hardly be expected that the discounts would be offered to the smallest consumers as well as to medium and large consumers. This solution of the problem is untried, and it is made merely as a suggestion, subject to qualifications and modifications through experience.

According to well recognized principles of differentiation, a central-station company is warranted in making concessions to the extent of almost the entire cost of transmission and distribution, in order to keep business that would otherwise go to private plants. In the long run, from the point of view of social economy, it is better that isolated plants be prevented from being built, if a rate that yields anything to the electrical company for transmission and distribution, in addition to a due share of other costs, will retain most of such business for the central station. Where density-factor economies are involved the consumer is entitled to a specially low rate. Herein is found the kernel of justification in the policy of the central station in relation to isolated-plant competition.

In order to deal fairly not only with the electrical supply company but with the public generally, it is important that the element of justifiable differentiation be duly recognized by commissions and courts. If the thing is ignored or the issue befogged by arguments that do not distinguish between justifiable differentiation, which we may call differentiation proper, and unjustifiable differentiation, for which the familiar name is "discrimination," there is much less likelihood of electrical rate schedules ever reaching a stable and generally satisfactory condition. Some concession to such consumers as can to advantage be supplied by isolated plants is justifiable on grounds of public policy.

## CHAPTER VII

## THE GENERAL THEORY OF DIFFERENTIAL RATES

*General principles* most clearly exemplified by electrical rates. The economic foundation of differentiation.

*No natural tendency to uniformity* in prices; uniformity sustained by the moral force of public opinion.

*The public the judge of homogeneity* of goods or services, differences being the occasion for price differences; electrical examples. Homogeneity in relation to *joint cost*. Degrees of jointness; illustrations. Joint cost *vs.* monopoly as the basis of differentiation. Differentiation might develop largely under competition. Danger of arguing from a single "cause."

*Wholesale discounts usually differential.* A differential element in retail price-fixing. Monopoly may promote uniformity of prices, especially for small consumers.

Deterioration and *cost often in proportion to time* rather than to use. Fixed-capital cost is of this nature. An improved cost accounting theory having regard to idle capacity. Bearing on load-factor cost for electricity.

The *limitations upon averaging* in rate making. A weakness of the class rate as such, except when used experimentally. Need of objective criteria.

*Service the ultimate standard* in judging differentiation. This principle opposed to rates lower than separable cost, as well as in favor of a differential treatment of general or joint-cost. Suggestiveness of electrical rates for impersonal methods. Public policy.

The study of electrical rates directs attention to principles which are generally applicable, and which are of special interest in connection with electricity supply only because they are there applied under circumstances peculiarly favorable to distinctness of development and clearness of explanation. The present chapter deals with these general questions. Some repetition of points made in other connections may be necessary.

The economic foundation for differential rates is the desirability of more fully utilizing a fixed-capital investment through the granting of specially low rates to business that can only so be obtained. Fixed capital is seldom or never utilized to its full capacity throughout a specified period, for example, a year. That the capital be utilized enough to earn a fair rate of return under existing conditions is not the point. "Full utilization," as the expression is here used, is a matter of economic technology rather than of finance.

A railway line operating only three or four trains a day furnishes an illustration of one important kind of low degree of utilization.

The electrical central station with a low load factor—indeed, with any sort of load factor actually experienced—affords another illustration of low degree of utilization, less generally appreciated, but even more forcibly appropriate. It is obvious that both these situations—and the load factor, moreover, usually acts in reinforcement of the density factor—stimulate the ambition of managers to get additional business, and they make profitable the concession of low rates, of course within limits, in order to get such business. In the case of the load-factor motive, however, not every sort of business will do. Moreover, the condition of the successful pursuit of a differential policy is that the higher rates from the older business, or the profits from that business, be not substantially impaired by the transfer of consumers from the old classes to the new class.

It seems to the writer that economists have tended to invert the natural order in assuming that the original or "normal" condition is one of uniformity of price for all the units of a homogeneous supply. It is generally assumed that uniformity of price—whatever that may mean—is natural and to be expected; and that, consequently, the investigator's task is to explain why and how differentiation emerges. The writer does not think this view is correct. Among primitive peoples, price, to the stranger at least, is determined by individual bargaining without reference to any standard. Even among peoples living under the conditions of Western civilization, especially outside the cities, uniformity of price, if it prevails, is something to be maintained by watchful care, rather than something from which any departure calls for explanation.

The forces that maintain price uniformity, or a "one-price system," furthermore, seem to be primarily moral and only secondarily economic. Competition prevents the shopkeeper from taking all the profit he can wherever he can, chiefly because each consumer becomes indignant if he finds ground for suspecting that he is paying more than others. The dealer known to be "fair" will get the trade. If, or so far as, a dealer can obtain a monopoly, he is, it is true, to a degree emancipated from this restriction imposed by the moral sentiments of purchasers. But even the monopolist will try to conceal or palliate discrimination. On the other hand, if the public will accept some kinds of differentiation as fair and reasonable, the

shopkeeper can practise these without the protection of a monopoly. The retail trader sells goods with the added convenience of city delivery for the same price as that at which he sells identical goods to be taken home by the purchaser. He is often ready to pay express charges on sizeable orders to be sent "within one hundred miles of New York." His cash and credit prices are the same. He holds "special sales" so far as he can do so without losing too much trade at the regular prices. Your corner grocer would in many cases be quite willing to charge a different price to each different customer for the same good if he could do so without offending the community's sense of fairness. Not in all cases, of course, for in many other cases his own sense of what is fair and just would restrain him, apart from any pressure of public opinion. All this, it may be said, is because the consumer is willing to let retail trade be less analytically competitive than the purchasing dealer is disposed to allow wholesale trade to be. But this influence is still primarily the moral factor. Among dealers themselves, certainly the most commercially minded are not those least inclined to "shade" prices.

One of the first things a combination does is to cut down extended and easy credits; that is, it does away with one sort of differentiation. Book publishers cooperate to maintain uniformity of prices. The entrenched monopoly seems to be quite as willing to lump consumers as to classify them carefully, though differentiation usually pays better, especially when the product is subject to competition from other kinds of business enterprises. But in this case, and to a less degree in others, doubtless economic factors are working in the same direction as the moral factors; notably, the cost to both dealer and consumer of making an individual bargain with each sale.

The scope of the public's demand that prices be fixed and uniform is, of course, limited by the perceptual discrimination of classes of goods as different from each other. But from an economic point of view it does not matter much just how the public draws the line between homogeneity and heterogeneity. Though the public still needs educating as regards classification, certainly at present it is disposed to tolerate much price differentiation.

Regardless of whether moral public opinion or strictly economic factors are the more potent in bringing about uniformity of prices,

it should be readily admitted that the only practicable way of determining what goods are homogeneous or what articles belong in the same class is to let the question be answered by the common sense of the public. Grounds for the acceptance of differences in prices may not appear in the material goods but in the supply of some associated service; on the other hand, the public may refuse to consider relevant differences in associated services, or in the goods or principal services, if the differences are small. In other words, two things belong for price-making purposes to different classes or to the same class according to what people in general think about it. If the public will accept a distinction between the carriage of cord wood and the carriage of coal a given number of ton-miles, the two services may be considered not homogeneous. Similarly the public may be willing to accept differentiation as between gas for fuel and gas for lighting, between kilowatt hours used for light and kilowatt hours used for power, between kilowatt hours sold to a church and kilowatt hours sold to a theatre, between a kilowatt hour that is one of ten supplied to one consumer in a month and a kilowatt hour that is one among ten thousand supplied to another, between kilowatt hours used for lighting before 6 P. M. and after 6 P. M.—or the public may not be willing to accept some of these distinctions. It is significant how well electrical supply puts to the test what sorts of goods and services one may consider homogeneous and what not.

In an important recent discussion of this subject the question as to what is to be considered joint cost, and what not, has been made to hinge on the definition of homogeneity.[1] This seems to the writer insecure ground. At least one would expect the definition to hinge on economic effects rather than mere physical qualities. The economic distinction between product and by-product should consist not in the fact that they are two—twoness is a relative as well as a commonplace matter—but in the fact that contributions to the two supplies are closely bound together so that one supply cannot be increased in quantity without increasing the other at something like the same rate. Let the two supplies be distinguished any way you will. Absence of interchangeability or of the possibility of substituting one for the other seems to be the proper economic criterion.

[1] Pigou and Taussig in the Quarterly Journal of Economics, vol. xvii (1912-13), pp. 378, 535, 687.

The form of the demand curve is significant, but hardly the decisive matter. If it were decisive, one might expect two articles absolutely alike to be sold to different individuals at different prices, for utilities differ even more than tastes, since circumstances, especially complementary relations, as well as natural and acquired desires and interests, affect utility.

Granted that the supplies are two, or that they cannot ordinarily be substituted for one another, degree of control possessed by the producer over the separate supply of each is the important fact. No doubt some qualification is necessary, to the extent that the exploitation of any by-product always involves some expense that would not otherwise be incurred, and this means that in no case is the supply of an economically serviceable article (an economic product) entirely unaffected by economic considerations or under entirely extraneous or non-economic control.

From this point of view, joint production is a relative matter. It is only the extreme case of a situation that is common, and also important, even where the characteristic element in the situation would not in all degrees be understood as one of joint production and joint cost. When there is a physical facility available for economic exploitation but largely unused, of which the possible extent of utilization is indefinite, the situation is certainly worthy of attention, whether we call it a case of joint cost or not. Quantity of physical performance may be in some determinate proportion to the service of a related demand though the performance is not of the nature of an economic supply. This is the case with back-haul empty cars. There is no economic supply until some small use is made of the empty mileage. The utility resulting from the unintended part (economically speaking) of the whole performance may be nil, in which case there is a failure of economic service or production. Or the situation may be that of physically idle, as well as necessarily at the same time economically unutilized, capacity.

An electric generating plant must be constructed with reference to taking care of the peak of the load. Its capacity at any other time of the day and year is to a large extent unutilized. Some plants in small towns shut down during the daytime. If capacity formerly unutilized comes to be applied to drive motors for manufacturing purposes, are not the kilowatt hours so supplied to some extent joint

products with the kilowatt hours sold for lighting purposes? If the intervals of small load can be further exploited, perhaps by the use of electric energy for refrigeration, does not the same question arise, to be answered in the same way? Yet carefully measured physical units of a given form of energy would seem to be about as homogeneous as anything can be.

A similar illustration is afforded by street railways. Transportation service offered may best be measured in terms of seat miles operated; and passenger service economically exploited or enjoyed may be measured in terms of passenger miles ridden. A street railway cannot possibly so arrange its schedule that these two match each other. Back-haul seat miles—especially important during rush hours—are in effect a by-product. Of course, most such seat miles are no product at all in a strictly economic sense; they are an incidental waste of energy that might have been productive. But any attempt more fully to exploit such seat miles would naturally treat them as a by-product.

These cases are analogous to that of a steam railroad that more fully utilizes its roadbed by differentially low rates for certain kinds of freight. That there is no fixed ratio between the quantities of the various economic services obtained from a single instrument does not seem to be of decisive economic interest. Even where the by-product is a material good, it may have any degree of importance subordinate to that of the main product, and the quantity obtained will often be made to vary somewhat according to its importance. It may be commercially worth nothing and still be a true by-product. Some cotton seed was always required for planting, but most cotton seed was long mere waste. The by-products of coal-gas manufacture are more variable and more subject to control, but they are not therefore less truly by-products, than the cotton seed. Indeed, the gas is the by-product and the coke the main product where blast-furnaces demand the latter. The different conditions of course involve differences in the quality of both gas and coke; which fact does not involve any change in underlying economic principles. If a strict conception of jointness of supply makes it a physical rather than an economic matter, then the economist is interested rather in the larger fact that some goods and services are available in quantities that do not vary directly in response to increase or decrease

in the demand for them. Under these circumstances it would seem not to make much difference how we determine whether one or more separate products or services are being supplied. The working distinction is made by consumers in their views on discrimination.

To repeat, the economy of full ultilization of product and capacity is the foundation of the significance of joint cost. Possibly, because of some restrictive formal definition that distracts attention from functional similarity, one may refuse to call all cases exhibiting the characteristic results of this situation cases of joint cost; but this seems to the writer unessential. The various cases belong functionally in the same general economic category.

The question whether joint cost—which the preceding discussion may warrant us in taking in the broad sense as relating to the economy of full utilization—or monopoly power is the cause of price differentiation has been much debated.[2] There can be no doubt that a monopoly would be inclined to differentiate, and since by hypothesis it has the power to differentiate, monopoly power is doubtless a sufficient cause of differentiation; in other words, it may be the decisive circumstance or influence. As to the modes of differentiation, a monopoly will, doubtless, both on economic grounds and from the need of conciliating public opinion, follow practically the course dictated by considerations of joint cost. There remains to decide the question whether joint cost could produce differentiation under competitive conditions.

Although competitive enterprises are much hampered by lack of control of the situation, just as they would be in instituting any price policy, it seems to the writer that a considerable degree of differentiation might still be developed. A 30 per cent annual load factor for an electrical enterprise is good. Will a plant that does not try to utilize the other two-thirds of its capacity by low rates be stronger competitively than one that does? Will not competition tend to cause the development of a differential system under such circumstances? If, indeed, the original consumers will not consider other than a straight kilowatt-hour rate (a kind of influence already dealt with), and if they have a choice between different

[2] J. M. Clark, in chap. 1, "Railways and the Law of Cost," of his Standards of Reasonableness in Local Freight Discriminations, traces the development and interrelation of the two points of view, but without coming to any definite conclusion.

sources of supply, it will not. But in fact consumers do not object to a lowering of the rate per kilowatt hour as the average hours' use increases. It is true that the company will be in better position to push its enterprise by way of differential rates if it has a monopoly hold on the original business. But the possession of large fixed capital only partly utilized seems to be more fundamental.

The situation of a railroad transporting chiefly freight is somewhat different, because the supply does not have to be provided at the moment of demand. It is the necessity of producing at the moment of demand which makes the electrical rate question peculiarly interesting. But the carriage of a consignment of freight cannot be long postponed without the loss of the business. Even for the road with the densest traffic, taking the year as a whole, there is bound to be some falling short of complete utilization. The more important element in the situation, however, is the fact that railroad lines are built long before they can be fully utilized. Hence if they can get low-grade freight by accepting less than the necessary general-average ton-mile rate, there will unquestionably be sound economic reasons for thus differentiating. Though the increase of business will in time require double-tracking, the average fixed charges per ton-mile carried will be less on a double-track than on a single-track road, so that even the imminent necessity of providing additional facilities will not much qualify the desirability of increasing business by differentiation. The American public does not expect that, after due allowance for incidental differences in methods of handling, coal and manufactured products will be carried at the same (or equivalent) rate. It is feasible, as a matter of fact, to treat the ton-mile sold to the coal-mine operator, to the dry-goods jobber, and to the copper smelter as different "commodities." Likewise with the kilowatt hours sold for domestic lighting and for elevator service. If a specially low rate is necessary in order that a railroad or an electrical company get a particular class of business at all, not only will that class of shippers or consumers demand such a rate, so far as is consistent with the profits of the public-service corporation, but public opinion, at least that of the mercantile community, will support such a demand. The problem of obtaining a great volume and especially a great variety of business in order to meet heavy fixed charges is

certainly not peculiar to monopolies and certainly has a formative influence on differential rates.

If we could find a branch of production requiring heavy investment in fixed and specialized capital where competition nevertheless ruled, and if we should find differentiation there practised in order to promote full utilization of plant, that situation would constitute the needed crucial instance. Ocean freight rates appear to yield approximately such a case. Competition is keen and differentiation is practised, especially in relation to "berth cargo." The printing and publishing business affords another approximate case. If we consider the use of a set of book plates in printing to be a homogeneous service and one for which an equal charge for each copy impressed may be expected, then the sale of a $1.50 and a fifty cent book printed from the same plates, and differing only in the quality of the paper and binding to the extent of a few cents, is a case of differentiation. Of course, for each single book copyright gives a monopoly; but for the supply of popular novels, or of serviceable school books, which are tolerably homogeneous as put out by various publishers, such differentiation is a competitive device. The devices by which different prices are paid for subscriptions to the same magazine constitute a similar example. The practice of charging less to new subscribers is well established and general.

One's attitude towards the debate on this question—whether fixed charges or monopoly cause differentiation—will naturally be influenced to a considerable extent by the degree to which one accepts or rejects a certain false premiss of much economic reasoning, to the effect that a given sort of economic phenomenon must be explicable by some single "cause." This is no place to argue the point at length; the writer can only state his opinion that any phenomenon is explicable only by a complex of many antecedents, conditions, circumstances, or "causes"—call them what you will—and that primacy among them is chiefly a matter of the various degrees of what "goes without saying," of what will be mentioned by one who is careful to be comprehensive, and of what calls for particular attention as the decisive factor under the circumstances assumed or described. To suppose that a specified sort of effect has one and only one cause seems to be a sort of personification of events and objects—a survival of fetichism. To illustrate by

reference to Marshall's analogy of the scissors, and to the controversy regarding the explanation of value to which this analogy relates, the writer believes it is correct to say that, where one blade is held in a vise, it is the moving blade that does the cutting, in the sense that its motion is the decisive factor and the rest is condition, circumstance, or what not. But it is equally possible that either one of the two blades may, in this sense, do the cutting; that is, that the decisive factor in the determination of value may be either on the side of supply or on that of demand. And it may be necessary to attend to both blades; their action will usually be neither entirely disparate nor of equal importance. Whether there is or is not a similar reciprocity of action between the two causes of differential rates, the illustration serves to emphasize the point that we need not regard monopoly power as the sufficient and only cause of differentiation, merely because by itself it may be made to provide a clear-cut explanation of the phenomena in question. Indeed, the joint-cost or full-utilization explanation goes to the economic foundations of the matter in a way to entitle it to a larger place than the monopoly explanation. Monopoly merely gives the economic and commercial motives of the dealer freer scope. What he will do if he has the power will be to fix prices in a way to utilize his fixed capital to the fullest, incidentally saving himself inconvenience by classifying his customers. Where he will charge high rates, and where low, is indicated by the joint-cost theory.

Although wholesale discounts are not ordinarily brought under the theory of differential prices, the writer has so classed them.[3] The fundamental reason for a difference in price according to quantity purchased is of course of an entirely different nature. But once such a difference is accepted, its degree may be differential in motive and effect, just as differences of quality and kind are exploited differentially. It has been also pointed out by the writer that the competition of the isolated plant, affecting only large consumers, may be considered a justification for some degree of differentiation of the same nature. The cases are again mentioned here chiefly to illustrate the broad scope of the principle. This particular case of differentiation through wholesale prices also serves to

[3] See page 1[illegible]3 ff., above.

illustrate the fact that differentiation is not absolutely conditioned by monopoly power.

The presence of a differential element in methods of retail price-making should also be noted in this connection. Retailers determine prices by adding to what was paid the manufacturer or wholesaler certain percentages *ad valorem* for handling the articles they sell. This procedure conforms to the principle of charging what the traffic will bear—since the purchaser of the more valuable article is charged more without specific reference to the character of the service performed—rather than to a policy of obtaining reimbursement for specific costs. The article that costs more at wholesale is not therefore of greater bulk or weight than the less costly article. Interest and insurance may add a trifle more to the basic original cost in the former than in the latter case. But such ascertainable differences seldom affect the percentages used.

In fact, a good case could be made for taking the absence of differentiation of the ordinary type in retail price-making as an earmark of entrenched monopoly. Such a monopoly is indifferent to the business offered by the individual small consumer, and is disinclined to adjust to individual needs prices made or services performed. Price uniformity is in fact decidedly economical if the buyers are small and where they have no option. We should therefore expect an adaptation of the method of differentiation to the situation described. That is what actually happens. Under such circumstances services widely varying in cost are often furnished at the same price, so that the profit varies greatly in a distinctly differential manner. This is one reason for the conventional nickel street-railway fare, though there are of course others. Monopoly tends to abolish careful graduation and external differentiation of rates. The fact that this tendency is a sign of monopoly power, however, should not be taken to imply that the change is never an improvement or never, even in the long run, pleasing to the public. At least, the suggestion is worth considering that the touchstone of monopoly policy is rather to be sought in connection with the treatment of small, than of large, consumers.

It has been argued that rates can be based on specific cost and in the long run should be; that all costs can be assigned to the pro-

ducts or services to which they are due on the basis of the proportionate use the products make of the means of production, and that, when this is done, there remains nothing to distribute differentially.[4] All costs certainly can be apportioned. But that fact of itself is no more significant than is the possibility of obtaining an arithmetical average of any fortuitous collection of numbers. It is also true that for most costs there is a fair and reasonable basis of apportionment. The exact whereabouts of the line of distinction between this problem and that of the disentanglement of separable costs—still by way of averages and for classes of commodities or services, not for individual consumers—may be difficult to determine.

Rails wear out, though it may take twelve or fifteen years, and their cost can be pro-rated on the basis of the use made of them, just as the cost of a trainman's wages is pro-rated over the objective services to which he devotes his time. But the likeness of the two cases is not complete. That the rails will have to be replaced sometime is not the fundamental point, though the brevity of the time during which a given kind of expense is effective—its rate of turnover, so to speak—is an important aid in the isolation of costs. The causal connection between use and cost is more likely to be close when the period of use is short, especially when there is but one use obtainable, as in the case of a processive good like fuel.[5] The crucial question, however remains this: Whether replacement becomes necessary after a given number of uses, and in proportion to *use*, or after a given period of *time*, with little or no reference to degree of utilization. If a locomotive's expectation of life in full service is determined by miles-run only and not by obsolescence and the like, then this element in cost per locomotive mile is determinate and separable; but if it is to be displaced at the end of ten or fifteen years whether it has run so many miles or twice as many, then average cost per mile is not something to build on, but merely a

[4] This appears to be the dominant point of view of our public-utility commissions. But since the fundamental problem for a rate-regulating body is the separation and just apportionment of costs, it is hardly to be expected that such a body will attempt nicely to distinguish separation from apportionment, especially since the two shade into each other.

[5] That is, in order that the so-called "variable" costs conform to the assumption ordinarily made, they must be special in time as well as special in incidence.

result of degree of utilization.[6] Deterioration of rails, for example, is not proportionate to use; still less is that of ties. In fact, depreciation in general is as likely to be due to rotting or rusting out as to "wearing" out. The cases where deterioration is more nearly in proportion to time than to wear and tear are numerous. Especially if obsolescence be taken into account, it is evident that the uses of fixed capital in general are, to a great extent, deciduous. If the fullest utilization is not made in season, certain potential uses are simply lost and the total cost has to be apportioned over fewer uses. Cost is, therefore, higher by reason of the failure of a fuller degree of utilization, such as might have been obtained, perhaps, by way of differentiation. Cost accountants are too likely to assume relations as fixed which may change as a result of prices based upon their cost analysis. Rates for electricity based upon load-factor considerations most forcibly illustrate the insecurity of amount of actual use of fixed capital as a basis of cost apportionment. Differential rates may lower cost. Though unquestionably cost analysis is important for this, as for any sort of price policy, a differential policy cannot be purely a matter of cost accounting after the facts have occurred.

Fixed-capital costs in general are in proportion to time rather than to use; hence the unit cost per use unit depends upon whether the price policy of a company promotes full use. This holds of carrying charges in general—of interest, rentals, and necessary dividends unqualifiedly, and of maintenance so far as proportioned to time rather than to use. In electrical industries obsolescence is particularly important. The importance of high degree of utilization as a reason for lower cost is clearer in the case of electricity supply than anywhere else because of the obvious special importance of the load factor as well as because of the importance of the more generally effective density factor.

[6] M. O. Lorenz in his article on "Constant and Variable Railroad Expenditures" in the Quarterly Journal of Economics, vol. xxi, p. 283, fails to see that these terms he employs as title do not sufficiently indicate the important distinction, which is between expenses that vary *with time* (or eternity), on the one hand, and those that vary *with amount of use*, on the other. Nor is it of great practical importance that, if a railroad could select from among the classes of business that come to it, after it has once become well established, it might be wise for it to take only the most profitable and not to expand—despite the importance of diversified loading and the applicability to the situation of the general principle of increasing returns.

A conspicuous instance of the fallacious assumption that apportionment according to some measure of use yields separated costs is afforded by the discussion of demand or capacity charges in connection with electrical rates. If we suppose that the peaks of all consumers coincide and directly constitute the station peak, the responsibility for the latter is quite definite. But in any actual case there is more or less diversity. Shall we discount each individual maximum demand in the ratio of the general diversity factor? Or shall we make the demand charge of each consumer proportionate only to his share in the station peak, that is, to his "simultaneous" demand? Shall we then exempt from any demand charge the consumer who requires no current at the time of the station peak? In that case, what if the load becomes smooth and nearly or practically constant for four or five hours of heaviest loading? Is not the whole question really one of policy, and should not the apportionment vary according to the needs of the company in building up its load factor? Some small plants can better afford to shut down during the daytime than to run at all. Others may have a daylight load about equal to their evening load. Is there any "use" rule of apportionment that will cover these extremes and the usual intermediate situation? Must not the company plan its rates with reference to the growth of business and adjust them accordingly from time to time, and is not this policy in contrast with, nay the opposite to, pro-rating costs and the procedure of most cost accountants?

It should be added that not all cost-accounting employs averaging and pro-rating in the uncritical way just mentioned. A cost-accounting theory that might be called differential though its origin does not appear to relate directly to differential rates has been advocated and to some extent put into practice. According to this theory, the burden of carrying and maintaining unused capacity, and a large share of overhead expenses in general, should be charged to profit and loss.[1] Such procedure would promote the utilization of otherwise idle capacity, even though at a minimum or partial profit. According to such a principle, it would not be necessary for a

[1] Cf. H. L. Gantt, The Relation between Production and Costs, in Transactions of the American Society of Mechanical Engineers, vol. 37 (1915), p. 112, and the following discussion; also, by the same author, Productive Capacity a Measure of the Value of an Industrial Property, in Journal of the American Society of Mechanical Engineers, Nov., 1916, p. 876. See also Chapter XII and elsewhere in Cost Accounting and Burden Application, by Clinton H. Scovell

manufacturer to throw overboard the results shown by his cost-accounting system in order to operate at all during slack times. Reserve or other excess capacity created in anticipation of future needs, or the result of ill-timed expansion of the fixed investment, would no longer be a drag upon operations.

If the theory be extended from ordinary manufacturing to electricity supply and applied in the light of load-factor considerations, and if it may be further assumed that the element of cost attributable to low load factor and to be charged to profit and loss is still a true cost for the business as a whole and to be recovered from consumers in some way, then, with such a sanction and guide, the policy of differentiation would have large scope. In the case of a company with a 30 per cent load factor, for example, the portion of fixed charges attributable to "idle" plant and to be treated differentially would have a relation, though not direct and numerical, to this ratio. It would tend to be smaller than 70 per cent to the extent that the use unit (the use of a kilowatt of capacity for a unit of time) would naturally be charged for at a higher rate during the peak time. On the other hand, the entirely differential burden of carrying reserve capacity would count towards increasing the proportion of fixed charges to be treated differentially. It would also, of course, be no small problem to determine the proper cost of a use unit at different times of day.

The extent to which the *averaging* of experienced or expected costs may properly be carried is a question involved in any method of rate-making having a claim to serious consideration. One set of extremists want to average everything on the basis of some single consumption unit—in electric supply the kilowatt hour. Even the extreme differentiationist, however, is not willing to consider making a separate rate for every individual. In the most general as well as crudest form of differential rates, namely, class rates, large groups of consumers are dealt with according to ascertained or assumed *average* service conditions and requirements. But the most refined differential policy does away with arbitrary class distinctions and attempts to make any classes it uses as homogeneous as possible. The differentiation may be continuous instead of by discreet steps—as in the case of a load-factor rate of the Hopkinson type. Such

differentiation by way of continuous variation is usually supplemented by some classification. Impersonal and impartial classification is rightly considered essential to justice in rate-making. The problems presented are the avoidance of arbitrariness in the lines of distinction, the avoidance of overlapping between classes, and the avoidance of heterogeneity or undue breadth of range within each class—all of them closely related to one another and susceptible of being summed up in the proposition that likes shall be put together and unlikes kept apart. And all three problems are perfectly solved in a rate that varies continuously according to some mathematical rule. In form, the superiority of such a rate is evident.

A business-developing policy, however, usually means the application of a new class rate. This is justifiable as an experimental method, though it is desirable that ultimately such a class rate be merged in a general system in which the method of classification plays a minimum part. One reason for the resort to class rates is the reluctance of the practical manager to disturb an existing rate structure to provide for the new possibility; he prefers to let well enough alone, at least to let any existing high rates alone. He wants to deal with dynamic elements as a separate matter and he may fail to see that the whole situation contains dynamic possibilities in greater or less degree.

The common preference of managers for class rates, at least in the just-mentioned aspect of the matter, is likely to be supported by public opinion to the extent that the class rates depend on easily identifiable *objective* criteria and easily discernible differences. But the requisite objectivity and definiteness attaches to things rather than to uses or to modes and conditions of consumption, hence the real purpose and function of a class rate may be lost sight of. Current supplied to a motor-generator set and then used for the light employed in moving picture apparatus is properly entitled to neither the ordinary lighting rate nor to the ordinary power rate. "Lighting" is not a sufficient description of the use. But to base the rate upon the simple objective fact that the energy is supplied to a motor can be regarded as adequate only where means are treated as end. The objective criteria of freight classification work better. But all classification reflects mere middle principles, valid only as working rules and methods of applying load-factor and density-factor prin-

ciples and such other knowledge of the causal connection between costs incurred and service performed as may be available.

The reader will observe that in the present discussion no such fundamental opposition is found between prices based upon cost on the one hand, and differential prices on the other, as is ordinarily assumed. Differentiation is properly based on cost analysis, but a kind of cost analysis that takes account of expected results as well as of present conditions; not on mere cost accounting, which is a much more limited thing. If we wish to keep strictly to the cost-accounting point of view, there is a degree of opposition between the cost element and the differential element in price, the former being separable in fact and the latter merely apportionable accordable according to some theoretical or arithmetical assumption. The writer can see little significance in the familiar, if not hackneyed, contrast between so-called "cost of service" and "value of service" theories. The latter seems to be a more plausible, only because rather high sounding, mode of stating the principle of "what the traffic will bear." Cost, in the broad sense, should be of more decisive influence than value. The latter under a well-worked out differential theory operates only through the effects of price (value) upon cost. Cost is therefore the fundamental matter. But cost itself must be judged with reference to the volume of service that ought to result from cost. The strongest argument for differentiation rests on the general social ground that such a policy favors maximum service to the public.[8]

From this point of view, aggregate cost, including therein a fair return upon capital (plus a premium for efficiency or minus a fine for inefficiency), should doubtless fix the aggregate of prices, since the rendering of the maximum volume of service requires that rates be kept down. It supposes low average rates because the lowest rates will be given to the most elastic or expansive kinds of demand, which will therefore count for most in the weighted average charge and cost in question. But separable cost fixes the lower limit of any rate for the obvious reason that an enterprise cannot prosper on out-of-pocket losses because there are "so many" of them. This statement is subject to qualification if there is a return to the com-

[8] That cost not normally resulting in service should have no direct share in price is properly a part of the same view. The service must be performed efficiently in order that the claim to the return of cost, including necessary profit, be justified.

munity that the recipient of the direct service will not adequately recognize in the price he is willing to pay for it; but service of this sort cannot ordinarily be brought within the scope of the rule under discussion, or, when such a policy is indicated, the enterprise should be conducted by the government and not as an ordinary business affair. However, it is only separable cost that must or can have a direct causal connection with rates for specified goods or services, and a quantitatively definite effect upon them. The remainder of total costs are properly apportionable according to general conditions and policies, so that the share allotted to a particular good or service is only in part due to its own characteristics. Doubtless all this is highly theoretical and will not by itself solve any concrete rate problem. But in matters of general policy—and differential rates come under this head—mistakes are due to a failure to develop clear ideas quite as ofton as to insufficient attention to the details of the concrete situation that confronts the practical man.

Electrical rates are of great importance in another respect; not only in the general way discussed in the foregoing pages, but also in the implied suggestions towards carrying out a differential policy impersonally. The principle of maximum service is too widely and variously indicated to be deemed a contribution from the consideration of electrical rates. But two-charge and three-charge rates—even though these also are not quite peculiar to electricity supply—are distinctive and are characteristically suggestive. The superiority of such multiple-charge rates as a method of differentiation consists in the even and balanced impersonality with which the differential policy—so often under suspicion for unjust discrimination—can be applied through their use. A single charge, it is true, can be so graduated that its variations are continuous. But it takes account of variation in only one dimension. Two principles of variation may be recognized by way of two charges; or, what is more to the point, one charge may be made to vary with separable costs and the other according to differential principles. The electrical-rate demand charge is properly treated in the latter way. Both the kilowatt-hour charge and the consumer charge, on the other hand, reflect separable costs.* And there is also need of differentiation

* The three-charge electrical rate is like what a railroad rate would be if it were composed of a terminal charge plus a mileage charge, and then plus something for the differential loading of fixed charges.

according to the diversity factor. The desired impersonal quality *appears* to attach to mere quantity discounts; but these involve concessions to mere bargaining power—which is directly opposed to impersonal justice in rate-making—and they encourage an artificial adjustment of service conditions. Pure quantity discounts should therefore be scanned with suspicion. Density-factor discounts are not open to the same objection. The "increment-cost" analysis that is ordinarily adduced in favor of an extreme application of quantity discounts in individual cases cannot be expected to result in the establishment of general and permanent rates. Classification as a method of applying cost analysis, even though the analysis be correct, is crude as compared with methods actually in use in electrical rate schedules—though doubtless actual rates, even where there is back of them adequate analysis with reference to the different variables, will be likely to employ classification rather than multiple charges.

From the rendering of maximum service to the public as a guiding principle, there is an easy transition to the fixing of rates with more or less reference to general considerations of public policy. To a certain extent this would seem to be a legitimate expectation in the case of corporations performing services "affected with a public interest." A private corporation, however, even a public-service corporation, cannot well carry the principle so far as a government enterprise may. For the former the rule nevertheless suggests itself: When in doubt, it is better to be public-spirited. Even though business men will transcend ordinary business principles and habits only when the application of these familiar guides leaves them in doubt, the twilight zone between what is and what is not separable cost is so important that the attitude suggested would be of considerable practical effect in rate-making. The rule of maximum service is itself a rule of public policy, and the policy of differentiation in general should be pursued in this spirit rather than in one of mere profit-making. The policy of differentiation is not necessarily a mere commercial device; it has a broad and firm foundation in economic principles that relate to enduring social welfare.

## CHAPTER VIII

## CONCLUSION: SUGGESTIONS FOR A MODEL RATE SCHEDULE

The obligation of local adaptation and of simplicity. The burden of proof. A rate schedule should be dynamic. The feature of a kilowatt-hour charge assumed; others to be discussed.

The load factor reviewed. The density factor reviewed. Latter to be disposed of first.

Suggestions for a schedule. A, Meter charges; B, Kilowatt-hour charges; C Density-factor discounts; D, Load-factor discounts for wholesale and other consumers; E, A commuted-rate option; F, Minimum combined rate per kilowatt-hour; G, Special rates, off-peak and other; H, Prices for lamps and special appliances; I, High-tension rates; J, Coal clause.

Politics as well as economics in rate-making. Technical questions and economic foundations. Immediate prospects.

In order to give a tolerably complete view of a rate schedule from an economic standpoint, it will be sufficient to deal mainly with the most highly evolved situation, such as is found only in the largest cities. Of course any discussion of what an electrical rate schedule should be must recognize the requirement that it be adapted to local conditions. The general propositions below are therefore necessarily subject to qualification. Even so, much of the outline will have to be left rather indefinite. The process of adaptation, however, will in general mean dealing with conditions less developed and less complex than those for which an ideal rate schedule would naturally be drawn up. In other words, we should expect such a schedule to be amended and adapted chiefly by way of simplification.

There is indeed not only a presumption against complexity, but also a presumption against change, unless it be in the direction of simplification. Rates resemble taxes in respect to the fact that what is simple and established should be considered best until proof to the contrary is forthcoming. For every feature of a rate schedule other than the straight kilowatt-hour charge the burden of proof is on the proponent. However, what is established or now exists in such schedules is generally not simple, hence constructive thinking in the direction of refined adjustments has freer scope than in most matters of applied economics.

Another fundamental requirement of an electrical rate schedule —and of rate schedules generally—is that it be progressive or dynamic in its influence. It should promote the expansion of business and the extension of the use of the service to the limit of what is economical from the viewpoint of society as a whole. No class of business that can be handled at a profit should be despised. Often the problem will be how to decrease costs so as to enter upon new fields of use. Sometimes the question is simply one of educating the public. In the case of an electric central-station enterprise, new uses and new appliances need to be investigated and pushed, and all possible consumers, within the limits of ultimate profitableness, should be reached. In the construction of a rate schedule such matters should always be reckoned with.

As to actual rate schedules, their failure to conform to any one or few settled principles makes it impossible to derive inductively a standard schedule from them.

The following suggestions will assume the justifiability of differential rates. It is also assumed without discussion that energy supplied under ordinary conditions will be metered and that there will be a kilowatt-hour charge. This position will leave open three questions as to important features of the rate schedule, namely: (1) how consumer cost should be dealt with, (2) when and how load-factor considerations should be recognized, and (3) what influence upon the rate schedule volume of consumption may be allowed to have and how that influence should be expressed. But the two most important questions relate respectively to the load factor, this being the special peculiarity of electricity supply, and to the density factor. The situation as regards these two is summarized in the following paragraphs.

The load factor is of special importance in electricity supply because in this industry supply must be synchronized with demand, since there is not the usual alternative possibility of storage. But in fixing rates, it is necessary to emphasize the fact that the station or company load factor, not that of the individual, is what is of special importance. With reference to building up a good load factor for the central station, diversity is at least as important as long hours' use by consumers of their individual maxima. From this point of view the consumer's simultaneous demand is more im-

portant than his maximum. The impossibility of economically ascertaining the facts about the load curve of each consumer, however, and the unsatisfactoriness of current methods of estimation, lead to the conclusion that, for small consumers, the situation may best be left to be taken care of by their known diversity—or the degree to which their consumption adds to the off-peak rather than the peak load of the station—at least in the case of a company that operates in a large city and has a developed daylight load. For large consumers, the ascertainment of the individual load factor and, not less important, of the individual diversity, is entirely practicable and should be made the basis of any concession of specially low rates.

The density factor as a ground for low rates is not familiar under that name and is not explicit in existing rate schedules. The suggestion of its explicit employment in such schedules is original with the present writer, so far as he knows, and is to be taken for what it is worth. It is proposed as a means of meeting isolated-plant competition, so far as that is permissible, on strictly economic grounds and in a way to prevent any sort of discrimination. It seems to be the only way of putting the wholesale concession on a sound economic basis in the case of electricity supply. Otherwise the granting of low rates seems bound to be influenced by bargaining power. The case for mere quantity discounts, except so far as the concession is actually due to density, is not as strong in the situation of an electrical company as it is in almost any other industry. Allowing landlords and others to profit by quantity discounts through "merchandizing," furthermore, is a most reprehensible form of rebating.

For the sake of simplicity (if for no other reason), in formulating the rate schedule, density should probably be disposed of by itself before load-factor considerations are taken into the calculation.

Other indicated elements in a rate schedule, drawn up according to what seem to the writer sound economic principles—but of course drawn also with due reference to various limitations not of an economic nature—may best be illustrated as a part of a scheme for such a schedule. In particular the method of applying the meter charge, which, as has been shown, has all the advantages of a consumer

charge and, at least in relation to small consumers, some of those of a demand charge, may best be indicated by way of such a schedule.

No importance should be attached to the absolute quantities and charges mentioned below; they will of course vary with conditions and are not even asserted to be appropriate for any known set of conditions. The relative quantities implied are somewhat more significant.

The various clauses of our hypothetical rate schedule are described for purposes of illustration, rather than formulated, in the following articles. It is not necessary for present purposes that they be practical in every detail. The illustrative purpose is an excuse for some degree of what may for practical use be considered over-refinement.

A. All consumers charged principally on the basis of kilowatt hours consumed will pay a meter charge. The smallest charge, for meters of 10 kilowatts or smaller capacity, will be 50 cents a month. The charge should increase with the size of the meter and should apply to each meter installed. This relates to standard watt-hour meters. The number and size of meters appropriate to the consumer's installation should be determined in accordance with rules acceptable to or prescribed by the district public-service commission. Extra charges for special devices should be required to conform to similar published rules.

Meters with clockwork and printing devices that record kilowatt hours for each 5-minute interval, which are used under contracts with consumers taking not less than 120,000 kilowatt hours a year, will in such cases be installed and operated by the company without other charge than for regular meters. But in the case of consumers taking less than 120,000 kilowatt hours a year who claim the benefit of load-factor discounts and have these load-recording meters installed with reference to obtaining such discounts, an extra charge should be collected sufficient to reimburse the company for the additional costs in question. But no consumer taking less than 12,000 kilowatt hours a year should be entitled to claim load-factor discounts or have the meters in question installed.

The meter charge does not apply for public street lighting, nor for flat-rate and similar contracts, where consumption is determined, not by meters, but by the time during which lamps are burned, or other apparatus used, and where the company's accounting with the consumer is also simple. This may include cases where the hours of use are controlled from the company's station.

B. Except as specificaly provided for elsewhere, each consumer will pay a kilowatt-hour charge as follows: For energy supplied up to 1000 kilowatt hours a month the rate is to be 6½ cents where

the consumer is classed as general and is entitled to the free supply and renewal of incandescent lamps. But the rate is to be 6 cents where such a small consumer takes energy only for power and does not require lamps; also, any consumer at his option, may supply his own lamps and thus obtain the 6-cent rate.

Energy in excess of 12,000 kilowatt hours a year will be charged at the rate of 5 cents per kilowatt hour under a contract for the full year (the actual rate being the average of the 5 cents for this excess and the 6 cents for the first 12,000 kilowatt-hour block), but with an additional half cent per kilowatt hour if lamps are included. This is the basic rate for all large consumers, but is subject to discounts elsewhere described and of course does not apply under special conditions, indicated in the rate schedule, entitling the consumer to a special rate.

C. Density-factor discounts will be allowed to each consumer, except as specified in E, on the basis of average consumption, within the street block to which he pertains, per foot of block front, according to the following rules. For energy supplied to such a degree of density as to raise the density figure for the street block to 80 per cent of the average for the system, a discount of 20 per cent on the kilowatt-hour charge for energy taken in excess of the 80 per cent up to a 150 per cent figure is allowed. In addition, for energy taken above a density figure 150 per cent of that of the system, a discount of 50 per cent of the kilowatt-hour charge on such energy in excess of 150 per cent is allowed. These discounts relate to the kilowatt-hour charge only and are applicable to each month's bill according to the density figure attained by the consumers in the street block in question during the month. But the actual amount deducted in each month shall be the amount earned in the preceding month, there being thus no discount made in collecting the first monthly bill and a discount due the consumer, upon his last bill, after discontinuance of service.

The average density figure of the system, however, is to be computed in absolute terms for existing conditions, and applied without modification for three years, at the end of which period it is to be revised according to the average figure experienced during the three years; and so on for each succeeding period. At each such time of readjustment the new standard density ratios will be submitted to the district public-service commission, which will determine whether or not a coincident readjustment of kilowatt-hour rates to give to consumers part of the benefits of gains in density is called for.[1]

[1] Experience will doubtless suggest modifications of these rules. Some means should be devised for allocating the contribution to density made by each consumer in a given street block, to which contribution the scale of discounts may be adjusted for other than the smallest consumers. Consumption in relation to floor space occupied seems to be a proper basis for such allocation.

D. Wholesale consumers taking not less than 120,000 kilowatt hours a year or more are entitled to a demand rate of the Hopkinson type instead of paying 5 cents per kilowatt hour. Any consumer taking as much as 15,000 kilowatt hours in any month must be charged upon this basis, except as noted under F. Consumers of smaller size, but such as take not less than 1,000 kilowatt hours a month, are entitled to this rate upon claiming it and conforming to the conditions prescribed in A.

The basic wholesale rate shall be $36 per year per kilowatt of demand plus 3½ cents per kilowatt hour. But the kilowatt-hour charge shall be subject to the density-factor discounts specified under C. The demand charge shall also be subject to discounts with reference to the diversity ratio, or else shall be based upon the mean of the consumer's individual kilowatt maximum and his simultaneous demand.[2]

The maximum demand of a consumer shall be determined by meter and, except as specifically otherwise provided, by one that records the consumption during each five-minute interval. The peak maximum demand of a consumer, except as specifically otherwise provided, is understood to be the highest recorded average kilowatt rate of consumption during any 30 minutes within the year. The amount of the demand charge due under the year's contract is thus not finally determined until the close of the contract year and must be estimated for each month according to definite rules, adjustment being effected at the close of the year. It is considered in conformity with the rule if the average maximum for the 4 winter months be taken as the consumer's maximum for the year and for every month whose maximum does not exceed this average, the demand charge for each such month of excess to be computed on the basis of the month's maximum. In the case of consumers whose load shows the normal seasonal variation, up to July 1 or thereabouts the preceding winter maximum will apply finally in all calculations; and after July 1 demand charges paid will be subject to revision according to results shown in the succeeding winter.

The electrical supply company may make any needed and reasonable regulations and stipulations providing for surcharges designed to compensate for or to depress large momentary demands

[2] The scheme of diversity ratio discounts might be as follows: Whenever the diversity ratio of any consumer under the demand rate shall exceed 20 per cent, that consumer becomes entitled to a discount of 1 per cent on the demand charge, and for each point per cent diversity ratio in excess of 20 he shall be entitled to a larger discount determined by adding 1 per cent to this figure. Thus, for a diversity ratio of 21 per cent, the discount will be 2 per cent; for a ratio of 22, 3 per cent; and so on. Where the diversity ratio exceeds 120 per cent or more no demand charge will be made. The diversity ratio will be computed for each month or other bill period with reference to the average kilowatt demand on the system during an hour (or longer period if preferred by the company) specified in advance by the company for the month in question.

and irregular fluctuations of the consumer's demand during peak or other hours.

E. Any consumer taking less than 1000 kilowatt hours a month shall, upon application, be given a rating for normal consumption in kilowatt hours per month, based upon character of load variation, diversity and intensity of use of appliances, and density of demand, as interpreted according to published rules, the normal figure so determined being subject to variation with reference to the four seasons in such a way that, while the average of the four seasonal figures shall equal the basic figure, the four may vary in relation to each other in substantial conformity to the seasonal variation of the need for lighting or in accordance with some other factor controlling the seasonal variation of the demand. In lieu of all other discounts—for load factor, diversity ratio, and density factor—a consumer so rated shall be entitled to a rate of 2½ cents per kilowatt hour for excess consumption above the amount specified in his rating. A consumer taking less than 100 kilowatt hours a month shall have available to him only this option in lieu of being billed at the standard rate.

F. The company may fix a minimum kilowatt-hour rate, after all discounts have been applied, of 1½ [?] cents straight per kilowatt hour for any wholesale low-tension consumer. This refers only to the per kilowatt-hour element in the rate and not to other charges.

G. Special rates (not covered by the published schedule) for certain specified classes of service may be offered by the company at not less than the smallest rate obtainable under the terms prescribed in D. Notice of any such special rate, explaining its purpose, shall be sent to all consumers who may be presumed to be interested by reason of similarity of service and other conditions. In general, the purpose of such rates is experiment and the development of new business. All special rates shall be optional with the consumer, but subject to discontinuance upon due notice at the will of the company and of the district public-service commission.

A straight kilowatt-hour rate of not less than the minimum kilowatt-hour charge obtained under D may be offered to exclusively off-peak service, reckoning the peak time at not less than two hours each day. But the consumer in such a case shall, in addition to the kilowatt-hour payment, recompense the company for all meter and administrative costs incidental to his special service.

Special breakdown and auxiliary rates and contracts for private plants shall be offered, but shall be conformable to the rules above stated.

Street lighting should receive a special rate, determined by contract with the municipality, conformable to the rules above stated.

Such special rates may be flat for street lighting, sign lighting and similar classes of service, but only where the quantity of energy

consumed is definitely ascertained through recorded hours of service and capacity of connected apparatus, or else where hours of use are controlled from a station or sub-station of the company.

H. Prices for lamps and all other electrical consumers' appliances supplied by the company shall be fixed each January 1st for the period of a year, subject, however, to reduction but not to increase, at any time during the year. For each consumer entitled to free renewals of lamps, at least one 40-watt lamp of the most efficient type in commercial use shall be supplied and renewed free of charge.

I. High-tension switchboard and primary rates shall bear an equitable relation to the above low-tension rates. The rate shall be either of the Hopkinson type or off-peak. All contracts shall conform to a published schedule, which shall include standard stipulations as to power factor and the variation of rates in relation thereto.

J. High-tension rates, off-peak rates consisting of a kilowatt-hour charge only, rates to private plants and others generating electricity, and any established kilowatt-hour minimum, may be qualified by a coal (or fuel) clause varying the specified kilowatt-hour charge with the cost of coal or of a specified number of heat units contained in fuel purchased.

It must be recognized that the electrical rate question is a matter of law and of politics—in no necessarily bad sense—as well as of economics. Doubtless much remains to be said on the subject from this point of view and much in the way of adjustment and compromise is necessary. These are matters with which this work does not profess to deal.

On the economic side a caution is necessary as regards certain possible future developments. If it ever becomes possible to store electric energy as cheaply and efficiently as, for example, it is now possible to store gas, load-factor considerations will become of negligible importance. Electrical rate schedules should then be expected to lose their present characteristic traits. The storage-battery is already applied to a considerable extent for smoothing out the peak of the load, at least in Europe, but it is available only for direct current and is costly in respect to both initial outlay and efficiency.

If in addition it should become possible to transport the stored energy cheaply, steam central-station electric supply itself would be completely revolutionized. In any case, as time goes on, through improvements in transmission and through enlarged facilities for

the storage of water, hydro-electric generation will become more important. But this development by itself will tend to cause an increased emphasis on load-factor considerations rather than the opposite.

However much the technological developments of the future may affect electrical rate schedules by changing the conditions presupposed in an economic analysis of the existing situation, there can scarcely be found a more interesting problem in rate analysis than is afforded by the subject of the present work. Nor is the significance of such analysis limited by the continuance of the dominant importance of the load factor in electricity supply.

In the long run economic considerations should control the policy and attitude of regulating bodies and courts towards electrical rates. Rates that favor the most economical, that is, the fullest, utilization of capital should be, not merely permissive, but prescribed. So long as the load factor has its present economic significance, the rendering of maximum service can be effected only through an appropriate rate schedule. The mere averaging of costs, whether by few or by many rate classes, and whether on a straight kilowatt-hour basis or according to some more recondite form of the idea that cost can be completely pro-rated per use unit, will not suffice. The consumer ought to be given an inducement to promote the lowering of cost. This is entirely practicable, at least with large consumers. Differentiation with a view to maximum service is needed.

Confronted with present conditions of economic uncertainty and unrest—which the electric central-station industry shares with other kinds of business without having had their opportunities for profits from the War—the practical central-station man will doubtless find the overshadowing problem of getting an adequate return a barrier to giving much attention to questions of detail as to comparative rates for different classes and conditions of consumers. Progressive economic changes, however, are especially likely to be nurtured by unsettled conditions. Rate readjustments will be initiated but not perfected under the pressure of emergency. More and more attention will be paid to getting the right kind of business and supplying existing customers through the right kind of rates. We may therefore look forward to the gradual elimination of arbitrariness or of the too free exercise of options by the company in determining

the consumer's demand under load-factor rates. And quantity discounts may be expected to be gradually purged of the suspicion of being unduly influenced by bargaining power. It is not possible to say exactly where a correct balance will be struck between over-refinement in adapting the rate to particular conditions and injustice in the grouping together of consumers with different characteristics; but it is safe to say that fuller knowledge of the facts pertinent to such determination will be developed and with it will come better application of such knowledge.

# INDEX OF NAMES

(Where a page number is followed by the letter *n* the reference is to a footnote.)

# INDEX OF SUBJECTS

(Where a page number is followed by the letter *n* the reference is to a footnote. At the beginning of each chapter is a condensed outline to which, also, the reader is referred.)